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16. ABSTRACT

This report is the third of a series of annual reports to Congress presenting a five-year projection of environmental research activities to be conducted by the U.S. Environmental Protection Agency. This year's report, however, takes a different approach than the two previous in that it focuses on potential environmental problems 10 and 15 years into the future in order to structure responsive solutions within the next 5 years.

Priorities for this years' Outlook were selected based upon priorities in national goals as expressed by Congressional actions and upon future trends in residuals entering the environment as a result of future energy resource and development patterns. Based upon these trends and legislative actions, 12 priorities were selected for emphasis in this Research Outlook: Toxic Substances, Atmospheric Pollution, Upper Atmospheric Phenomena, Solid Wastes, Industrial Pollution, Nonionizing Radiation, Energy and the Environment, Nonpoint Discharges, Marine Pollution, Measurement and Monitoring, Strategy Analysis, and Technical Information Dissemination.

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Foreword

We have no magical ability to predict what changes the future will bring or what responses will be required of our research program. In projecting our program into the future, we rely on three major sources of guidance. The first is the legislation passed by the Congress and signed into law by the President. The second is the model-based projections of major economic and industrial trends. The third is our experience and best insight. The former two sources are discussed in some detail in this volume. The third source was derived from the more than 300 Agency scientists and engineers involved in preparing this report.

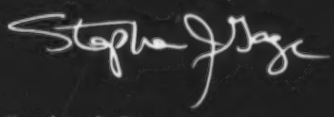
In contrast with the two previous versions of EPA's Research Outlook, this 1978 edition does not begin with our program as it is. Instead, we seek to identify developing environmental issues over the next 10 to 20 years in order to structure our research for the next 5 years. Our approach should give the reader some insight into the perceptions and motivations that shape our program and actions.

It is through this type of insight that we hope to achieve two basic goals: the first is communication, the second is trust.

By setting out our priorities for open debate, we are beginning a process of communication and interaction which will help to shape EPA's research strategies in the years to come. The efforts and initiatives discussed in this volume must be conducted somewhere within the Federal environmental research and development community. Not all of the efforts outlined here are expected to be conducted by EPA. Some efforts may be more appropriate to other agencies. (EPA, after all, conducts only about one-fifth of the total Federal environmental research effort.) Regardless of where the efforts are conducted, however, a structure is necessary to assure effective communication of research priorities, from the management level, and of research results from the laboratory level. It is one of our most important tasks to see that this communication/coordination is effective within our multiagency context.

The second goal of this report is to begin to develop an increased trust in our judgment as researchers and research managers. We hope that, by spelling out our most important priorities and philosophical approaches in those areas which can be discussed in non-technological terms, we will improve your trust in our decision-making processes. Like any other form of human endeavor, science is as much intuition and instinct as it is precision and certainty. To protect us from potential crises five years hence, we must begin our research into these areas today. Often we must begin with little more than a well-educated guess—a feeling about where the key answers may lie. It is just such a process on which some of the finest scientific achievements are built. We hope that, with the background provided by this report, we will help to gain the trust we need to invest all of our resources—money, expertise, creativity and dedication—to best resolve the environmental problems of today and avoid those of tomorrow.

With the issuance of this year's Research Outlook, we are already well on our way to preparing for next year's version. That edition, it is expected, will provide additional detail on the projects and programs necessary to meet our priority requirements. Your review and comments on this year's Research Outlook are welcomed. Such comments serve to improve these documents and the detailed program which develops from them.



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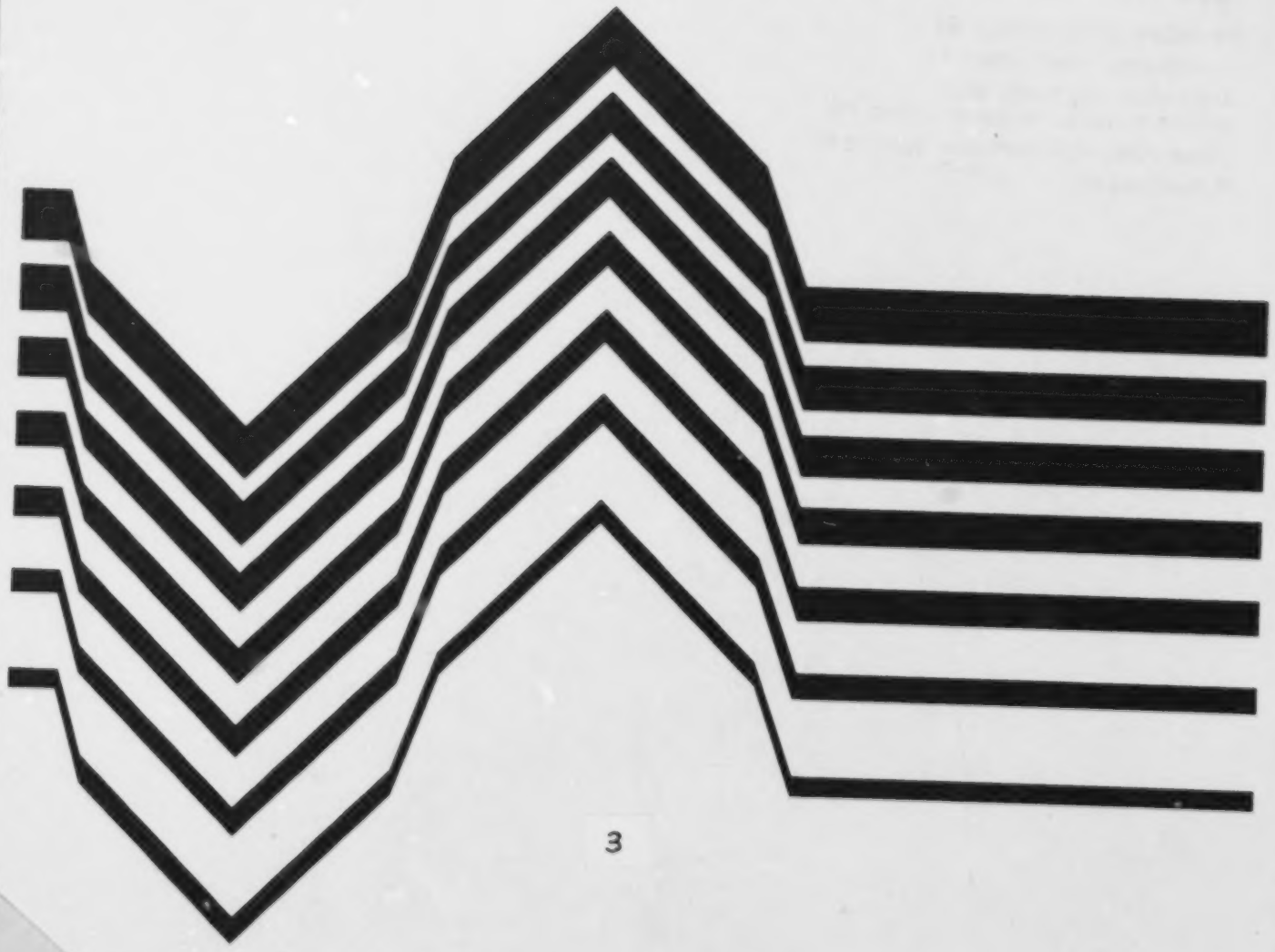

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Summary

The *Research Outlook* provides a glimpse, however murky, at those environmental issues that we expect to become problems over the next two decades. Where these problems can be clearly seen, or where Presidential or Congressional guidance is explicit, our discussions are more detailed and precise. Where the future vision is less clear, we rely on our experience and expertise to give shape and substance to potential problem areas. In either case, this *Outlook* represents an important first step in translating what our knowledge and instincts tell us into a framework for defining future research to strengthen the nation's capacity for dealing effectively with tomorrow's environmental problems.

The topics covered in this report were selected to represent problem areas of major concern. By no means exhaustive, these topics reflect our best estimate of the trends and factors which should drive future environmental research. Each of these eight topics—toxic substances, air pollution, energy and the environment, solid waste, global pollution, nonionizing radiation, nonpoint sources and watersheds, and measurement and monitoring—were selected because of their relationship to severe threats to human health and the natural environment. The following chapters present a sense of relative priority for dealing with each of the problem areas, a set of health and environmental protection goals to guide our research efforts on these potential problems, and a brief description of the relative level of resource commitments required to ensure significant progress toward meeting the goals.

Toxic substances—prediction and control

Our advanced industrial economy relies on thousands of substances which did not exist on this planet until the last few decades. These substances were developed because of their extraordinary properties of strength, durability, reactivity, conductivity, or toxicity. Americans—as well as the citizens of all industrialized nations—are exposed to these substances with every breath of air, drink of water, and swallow of food.

Presidential and Congressional recognition of the pervasive threat of environmental toxicants to human health has now taken form in the Toxic Substances Control and Resource Conservation and Recovery Acts and the amendments to the Clean Air and Clean Water Acts. This re-chartering of EPA's mandate to protect public health demands that the **highest priority** research area be the prediction and control of toxic substances.

To control toxic substances, we must first predict their environmental behavior and effects. Every research tool at our disposal—epidemiology, toxicology, and chemical analysis—must be used to accurately predict the harmful biological effects of any chemical through any exposure route. The early development of rapid testing procedures—our highest priority in the short term—is necessary to provide this capability to predict. In the process, we must develop a fuller understanding of the biochemical mechanisms involved. Such mechanisms are complex; it will be necessary to explore many different testing procedures to assure a greater likelihood of success.

To test such a large number of chemicals, they must first be grouped, if possible, according to their potential effects. These groups should then be ranked according to their potential hazard. Then we need to relate these groupings of chemicals to genetic and reproductive effects in order to protect future generations. Next, we need to avoid the risk of damaging human development, aging, and behavior; and, finally, we need to eliminate risk of disease or early death.

One approach to determining the toxicity of chemicals is to test each chemical through a screening system. Chemicals can be screened by chemical and biological methods. Multiple tests can be used to sequentially screen chemicals as safe, unsafe, or possibly unsafe. Each test in the sequence is more expensive than the previous test, and the successive steps would be required when a chemical has been determined to be potentially unsafe. The cost

of further testing in the sequence could reduce the potential commercial benefit of the chemical, hence bringing economics to work in protecting public health.

Such screening efforts must not only test the chemical itself, but must also consider the physical, chemical, and biological processes which may change the chemical once it reaches the environment. Such natural processes as exposure to sunlight, to water and dissolved substances, or to the metabolisms of living creatures could transform an initially harmless chemical into a toxic one. If we do err in our screening efforts, we must err on the side of falsely indicating that a harmless substance is possibly unsafe, thus requiring further testing, rather than falsely indicating that a toxic substance is safe.

Air pollution—the ubiquitous aerosol

During the past two decades, we have developed some understanding of the effects of gaseous air pollutants such as carbon monoxide, ozone, and sulfur oxides. Our attention is now shifting to the complex of aerosols* which pollute the air over large areas of the country.

Aerosols come from many sources. The increased combustion of coal, for example, is expected to contribute greatly to sulfur and nitrogen oxide emissions during the next 15 years. These pollutants are precursors—chemical forebears—of secondary pollutants of higher toxicity (e.g., sulfates and nitrates). In the process of this transformation, these gaseous pollutants may go through a formative aerosol phase during which they combine with water in the atmosphere to form acids. These acids, it is now thought, then react with metallic air pollutants to create the sulfates and nitrates which may be among the toxic pollutants from which we suffer. Adding to these aerosol problems are the complex secondary pollutants generated in the urban atmosphere by reactions of hydrocarbons and nitrogen oxides, largely produced by automobiles and trucks.

In addition to its chemical properties, the biological hazard of an air pollutant also depends upon its size. Larger aerosols may be captured by the body's defense mechanisms—the mucous linings of the sinuses and throat—and then swallowed. This can cause harmful effects via the digestive tract. The smaller and more typical aerosols may be carried deep into the lungs, where they may be capable of creating severe effects, such as exacerbating emphysema or causing lung cancer.

Because of the likely growth of atmospheric aerosols and their pervasive threat to human health, understanding and controlling such aerosols must be the **second highest priority** research area. We must improve our knowledge of how aerosols are formed in the atmosphere and how they react and move long distances. We must improve our understanding of the relationship among the exposure, type, and size of aerosols; the ability of the human body to counteract the effects; and the ultimate damage to the body. Although the experiments required to understand such subtle effects are more sophisticated than traditional inhalation experiments with gaseous pollutants, it is important that we accelerate our health effects studies on atmospheric aerosols.

In addition to their impacts on human health, aerosols combined with other air pollutants can lead to poor visibility and acidic precipitation. With an improved understanding of aerosol formation in the environment, we can then use maps of pollutant sources and environmental conditions to better predict exposure routes and patterns. These predictions can then be used to support more precisely targeted efforts to control pollutant emissions.

*Aerosols are fine bits of matter suspended in air. Often in a state of transition, they can contain solids, liquids, and gases at the same time and can undergo chemical reactions which gradually change their properties. Aerosols are formed out of the "chemical soup" of pollutants in our atmosphere, and, when inhaled, may be extremely harmful.

Energy and the environment—assuring compatibility

The National Energy Plan requires that we conserve our oil and natural gas by shifting to greater reliance on coal and conservation and, to a lesser extent, on nuclear power and oil shale. Determining the possible consequences of these alternatives provides the rare opportunity of using foresight rather than hindsight to control our national development. Our main priority is to predict and control any health and environmental risks from toxic substances and atmospheric aerosols resulting from coal combustion and conversion processes. Because of the close interrelationship between this area and the two higher priority areas and the potential impacts of massive shifts to coal, this area is the **third highest priority** research area.

Solid waste—turning wastes into assets

The growth in tonnage of solid wastes over the next 15 years is expected to be much greater than that of airborne or waterborne pollutants. This increase is attributable to economic growth and to the improved control of pollutants which would otherwise have been released into the air and water, but are now being removed in solid or semisolid forms. A significant fraction of this waste, especially industrial sludges, contains toxic substances.

Because of the rapid growth in quantity and the growing awareness of the toxic nature of some of the wastes, this area is the **fourth highest priority** research area. Methods must be developed which will prevent toxic solid waste from being released at handling and disposal facilities in the form of dust or leachates. Our main priorities are to prevent such release by developing detoxification techniques, recovering waste as a resource, substituting products that result in less waste, and informing consumers of less wasteful alternatives.

Global pollution—earth's survival

The ability of the earth's biosphere to continue to absorb the brunt of human activities has recently been hotly debated on at least three issues—the threat of depleting our protective ozone layer, the increased release of carbon dioxide into the atmosphere, and the increased exploitation and pollution of the oceans.

Because of potential long-term importance of such subtle effects to all people, understanding and predicting the effects of human activity on the biosphere is the **fifth highest priority** research area. We should study the combined effects of human activities in the oceans, the troposhere, and the stratosphere. A better understanding of natural global cycles may be necessary if we are to determine how these cycles are affected by human activities. For example, since the nitrogen cycle is emerging as a possible prototype for understanding the limits to the buffering capability of nature, we could focus increasingly on improving our understanding of the global nitrogen cycle.

Many nitrogen compounds are toxic. Nitric oxides are precursors to airborne nitrates and airborne nitrates may be an important element of increased acidic precipitation. Nitric oxide emitted by high altitude aircraft may also deplete the stratospheric ozone layer. Nitrites and nitrates can pose health hazards when leached into sources of drinking water. Nitrogenous compounds in coal and oil shale may also require strict controls to protect human health. Research into these areas should provide important pieces to the puzzle that is our global environment.

Nonionizing radiation—effects of the unseen

Our exposure to nonionizing radiation from radio, television, electrical transmission, and microwave sources is growing rapidly. Growth in such exposure and some disquieting research results strongly support the expansion of research in this area to determine if more stringent control of electromagnetic radiation sources is necessary.

This—the **sixth highest priority** research area—is aimed at understanding the more subtle, nonthermal effects of nonionizing radiation and its possible impacts both alone and in combination with other stresses. Prime candidates for expanded research are the effects of radiation in the communications (microwave) and commercial (UHF-TV) radio frequency bands.

Nonpoint sources of pollution—limits to assimilation

Within a decade, the major point sources of pollution (industries and municipalities) are expected to be well on their way to controlling the most significant water pollutants. A larger (in terms of sheer volume of pollution) and perhaps a more intractable problem is the control of water pollutants from farming and forestry, poorly planned land uses, atmospheric pollution fallout, and other such nonpoint sources. Such influences can have severe immediate and long-term impacts on watersheds and, eventually, upon groundwater.

Because nonpoint sources will remain the major sources of water pollution over the next two decades, understanding these sources and being able to predict their impacts on watersheds is the **seventh highest priority** research area. Land use fundamentally modifies a watershed and its ability to store water. This factor can alter the productivity of the land, the quality of downstream water, and the purity of groundwater. Once contaminated, our groundwater resources—a major source of drinking water—may require generations for reclamation, and such contaminants can travel in unexpected directions. We cannot afford to lose groundwater resources as a result of unguided decisions. We must provide adequate predictive information to local or regional decision-makers regarding the environmental implications of their actions. Finally, rain containing air pollutants imports acids and other substances into the water basin. This rainfall can then leach nutrients from acidic soils, thus requiring greater use of fertilizers if land is to retain its original productivity. We must, therefore, determine if regionally based air quality control strategies are required to protect the productivity of the land and water.

The watershed integrates the impacts of many pollution sources—both point and nonpoint. It thus emerges as the key hydrological unit upon which to base our studies of water pollution.

Measurement, monitoring—telling what's where

The detection of the multitude of different pollutants at various locations throughout the country is, at present, prohibitively expensive. More precise and cost-effective methods and equipment will be required before a comprehensive monitoring system can be provided. At the same time, a firm commitment should be made to a disciplined, long-term monitoring effort to accurately describe our physical, chemical, and biological environment and to improve our understanding of the dynamics of that environment.

In this **eighth highest priority** research area, we should not only emphasize the accurate gathering of data during the next few years, but also the linking of the many data bases now or soon to be available. Through such linkages, we may expect to discover causal relationships between the various components of the complex system we call the environment. The discovery of such relationships, especially concerning toxic substances, can vastly improve our ability to anticipate pollution problems, which may threaten human health, and to focus our resources where they will be most effective in preventing those problems.

All things are poisons; for there is nothing without poisonous properties. It is only the dose which makes a thing a poison...

Paracelsus
1493-1541

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Toxic substances

Goals

The goals of the toxic substances research effort are to reduce the threat of toxic substances to human health and the environment by improving screening tests for the toxicity of substances, to detect the presence of potential toxic substances through studies of historical health and disease patterns (epidemiology), to determine how each major toxic pollutant travels through the environment, how it changes, and how it affects humans at various dose levels, and, finally, to develop improved means of controlling these pollutants.

Since 1945, there has been a rapid increase in industrial development, particularly in the production of chemicals. More than four million distinct entries are now contained in the Chemical Abstracts Service of the American Chemical Society, and the Service's chemical registry is growing at the rate of about 6,000 new chemicals per week. (Ref. 1). There may be 50,000 chemicals in common use excluding pesticides, pharmaceuticals, and food additives (Ref. 1).

Toxic substances cause adverse environmental effects ranging from mild temporary dysfunction of organisms and ecosystems to acute symptoms, disorders or death. Some toxic substances cause cancer. Some estimates are that up to 90 percent of all malignancies may be induced by, or related to, environmental factors (Ref. 2) such as smoking, diet, stress, and air and water quality.

In this context, environmental factors include all stresses within the human environment, with the exception of an inherited susceptibility to cancer. Environmental factors include both voluntary and involuntary exposure to carcinogenic substances, smoke, X-rays, occupational and household toxicants, water pollutants, naturally occurring toxins, and "life-style" traits such as delayed childbirth.

Statistics on cancer mortality collected since 1900 indicate increased cancer death rates. From 1933 to 1975, there was an annual increase of about 1 percent. After 1975, that rate grew to 2.3 percent per year (Ref. 2).

Part of this increase is attributable to an overall aging of the population. Cancer is primarily a disease of middle and old age, and our current living conditions allow more people to live to an age when cancer is likely. Better diagnostic techniques and improved reporting procedures in cases of death may also account for some of this increase.

Most observers believe, however, that there has been a true increase in the total cancer death rate* in the United States, especially for men. Although attributable in part to a greater susceptibility to lung cancer related to smoking, increases in mortality for both white and nonwhite males (20 and 60 percent, respectively) indicate a need for an expanded research effort on factors related to occupational and environmental exposures (Ref. 3).

Many potentially toxic chemicals are components of consumer products. These include tars from cigarettes, chloroform in cough medicines, benzene in paint remover, and "Tris" in children's pajamas. Substances such as asbestos and vinyl chloride have been linked to incidences of cancer among exposed workers. Recently, potentially toxic substances have been identified in several drinking water supplies.

The toxic substances problem is so great that resources available throughout the Federal government must be mobilized and coordinated to meet the challenge. An excellent start is the recent formation of the four-member Interagency Regulatory Liaison Group. The members are EPA, the Food and Drug Administration, the Occupational Safety and Health Administration, and the Consumer Product Safety Commission. EPA also maintains strong ties with the Food and Drug Administration's National Center for Toxicological Research. EPA has participated with the National Institute of Environmental Health Sciences in identifying research needs in, and developing implementation plans for, human health and the environment.

Research can improve our ability to identify mechanisms which lead to biological end-points—effects produced by the same or different chemicals acting through one or more mechanisms. Such effects are expressed in terms of an alteration of some known physiologic or biochemical process. When complex processes are involved, the tasks of identifying the ways the chemicals can interact and defining cause-and-effect relationships are more difficult.

In addition, there is a serious need to define the behavioral, developmental, and aging effects from exposure to toxic agents. Behavioral changes could be studied for possible use as sensitive indices of acute and chronic toxicity. Developmental and aging phenomena may be of similar utility as indications of a toxic response. All of these areas

*For more information on the rates and risks of cancer, refer to "Cancer Rates and Risks" prepared by the National Cancer Institute (Ref. 3).

help to refine our ability to identify for control those substances which are toxic to humans.

Controlling the problem

Industry releases waste into the air, water, municipal sewage treatment systems, and onto the land. The composition and quantity of these substances depend on the industrial process employed. For example, in the production of copper, pollutants containing arsenic, cadmium, lead, and sulfur oxides predominate. Conversely, the meat processing industry waste streams contain organic materials such as animal fats and organic nitrogen compounds.

The amounts of toxic pollutants reaching the environment will be reduced through the application of "best available" control technologies to air and water waste streams. However, stringent control of air and water pollutants also means that those pollutants are converted to solid or liquid residuals. These residuals must either be recycled or dealt with through some form of land disposal.

Current methods of disposal and recycling of wastes and byproducts may ultimately compound the health and ecological effects of substances introduced into the environment. For instance, inadequate land disposal techniques can lead to the assimilation of toxic substances by plants. Pesticides or industrial wastes in uncontrolled runoff can enter streams and be absorbed by aquatic organisms, shellfish, and finfish. These chemicals can accumulate through the food chain to affect higher order predators. Part of the reason for banning the pesticide DDT, for example, stemmed from its apparent role in reducing the thickness of eggshells and, hence, the survival rate of fish-eating birds.

The ability of various species, including humans, to accumulate particular toxic materials is poorly known and should be carefully investigated. To support this effort we need to develop predictive tools to simulate the dynamic physical, chemical, and biological interactions of toxic substances after their release into the environment.

We must improve our knowledge of sources of toxic substances formed by atmospheric chemical reactions. For instance, we should expand our attempts to determine if carcinogenic or toxic materials such as nitrosamines are formed in the air above urban industrialized areas. A combination of laboratory and field experiments will probably be required to connect the secondary atmospheric sources of these materials, if found in the atmosphere, to the primary emission sources.

We have made significant progress in controlling such water pollutants as oxygen-depleting substances and nutrients. On the other hand, our surveys are identifying hundreds of toxic substances in surface and groundwaters. Throughout the nation, heavy metals, organic compounds, radioactive materials, and other hazardous substances have been measured in both surface and groundwater. These substances occur in amounts ranging from trace levels to toxic concentrations (Ref. 4, 5). This contamination is especially acute where the receiving waters are subject to drainage from industrial wastewater impoundments and solid waste disposal areas (Ref. 4, 5). For a fuller discussion, see the chapter on *Nonpoint Sources and Watersheds.*

Once a body of water, especially groundwater, is polluted with toxic materials, decontamination using current technology is extremely expensive if not impossible. Two prime examples of this are leachates from coal mine tailings and organics in industrial effluents—both serious and growing problems requiring additional development of control technologies.

To prevent toxic substances from reaching drinking water supplies, greater emphasis is being placed on developing control technologies to remove toxic pollutants **before** they

Possible Ames Test Results

Positive Agent appears mutagenic via Ames test and is also found to be mutagenic by other tests.	**False Positive** Agent appears mutagenic via Ames tests, other tests (e.g., whole animal) indicate that it is not a mutagen.
Negative Agent appears not to be mutagenic via Ames tests, other tests indicate that it is not mutagenic.	**False Negative** Agent appears not to be mutagenic via Ames test, other tests, however, indicate that it is, in fact, mutagenic.

- False negatives are a problem because those mutagenically active components, when tested by the Ames method, appear nonmutagenic and, hence, are no longer considered important.
- In these bioassays, it is imperative to conduct a battery of tests, so that the chance of false negatives occurring is reduced, i.e., the Ames test may overlook a mutagen (false negative), while a backup test would/might not.

are discharged. One technique offering great potential for reducing the amount and toxicity of industrial effluents at minimum expense is process or feedstock modification. Many existing industrial plants and processes were developed with little or no concern for the toxicity of their waste products. Sometimes relatively minor modifications to the processes or the chemical feedstocks can reduce or eliminate a potentially severe effluent problem. Additional research in this area could produce dramatic results by reducing pollution at a lower cost than for alternative end-of-the-pipe technologies.

Toxic substances may also be released to the environment as solid wastes. With recent enactment of the Resource Conservation and Recovery Act, research efforts are being initiated to develop improved solid waste management techniques and to understand the movement of hazardous substances through the environment. The *Solid Waste* chapter discusses this problem in detail.

Predicted Discharge of Toxics to Water[a] 1975 to 1990

Toxic Material (Dissolved Solids)	Industrial Chemicals	Other Chemical Products	Non-Ferrous Metals	Steel	Fabrication	Electric Utilities
Cadmium			8%	0%[b]		
Chromium	170%	0%		29%	0%	
Lead			0%	5%		47%
Mercury	7%		2%			
Zinc		149%	2%	4%	0%	
Aluminum			0%	0%		
Copper	45%		0%		0%	18%
Cyanide				9%	0%	
Ferrous Metals				0%		
Fluoride			5%	33%		
Selenium			17%			
Titanium Oxide[c]	24%	0%	0%			
Titanium Oxide[d]	1%					

[a]Data are 1990 values as percent of 1975 values.

[b]Value in 1990 is reduced to negligible amount from 1975 level.

[c]Suspended solids.

[d]Dissolved solids.

Source: U.S. Environmental Protection Agency, 1978.

The research response

Five areas of research emerge as key to identifying and controlling toxic substances:

—improve screening tests,
—conduct historical health analyses,
—determine how pollutants travel and where they end up,
—identify human exposure to toxic pollutants, and
—identify improved control methods.

Improve screening tests. We must improve techniques for rapid screening of toxic substances, especially for mutagenic and carcinogenic effects. Substances which cause these effects are among the most dangerous to our health and the viability—survival—of future generations. We must know for certain what and where these substances are.

The Ames test, a relatively well established measure of mutagenicity, is expected to be validated by the National Cancer Institute in 1978. However, this is but one of several tests that can determine the biological hazard of a substance.

Another method for testing the mutagenicity of substances is to expose living organisms to these substances and monitor their response. Such testing on whole animals and cellular material should be improved both in terms of accuracy and costs. To relate these approaches more directly to human health concerns, the use of test cultures employing human cells should be emphasized. In addition, short-term tests for substances which cause birth defects and other reproductive effects should be developed.

Determine historical health effects patterns. Systematic investigation of exposures and effects based on historical data provides a way to check the toxicity of a substance based upon the health records of individuals who have been exposed to that substance. Epidemiological data—from hospital admittance, diagnosis, and post-mortem examination—may be used to identify existing dangers from exposure to different toxic substances. Correlations of such data—confirmed by surveys of occupational or environmental exposures, studies of tissue burdens, and disease analysis—will help not only to identify sensitive populations but also to assure an adequate margin of safety to protect the general population. Development of exposure effects correlations based on historical

data may be facilitated using the UPGRADE system described in the chapter on *Measurement and Monitoring*.

Investigate how pollutants travel. In most cases, accurate knowledge about what happens to a toxic substance after it enters an ecosystem—how it travels through and is changed in the environment—is not now available. The problem is extremely complex. The routes and transformations of toxic substances, especially in the aquatic environment, and the resulting exposure of humans and other living creatures require further understanding.

Toxic wastes can be concentrated in the food chain. For example, mercury and cadmium levels in fish, shellfish, and their predators are far higher than the levels in their food or surroundings. To better understand this process of bioaccumulation, indicator species—species whose response to specific toxic substances is well known—should be identified and monitored. Profiles of how selected "benchmark" chemicals behave in the environment should be developed to predict how related chemicals act under similar conditions.

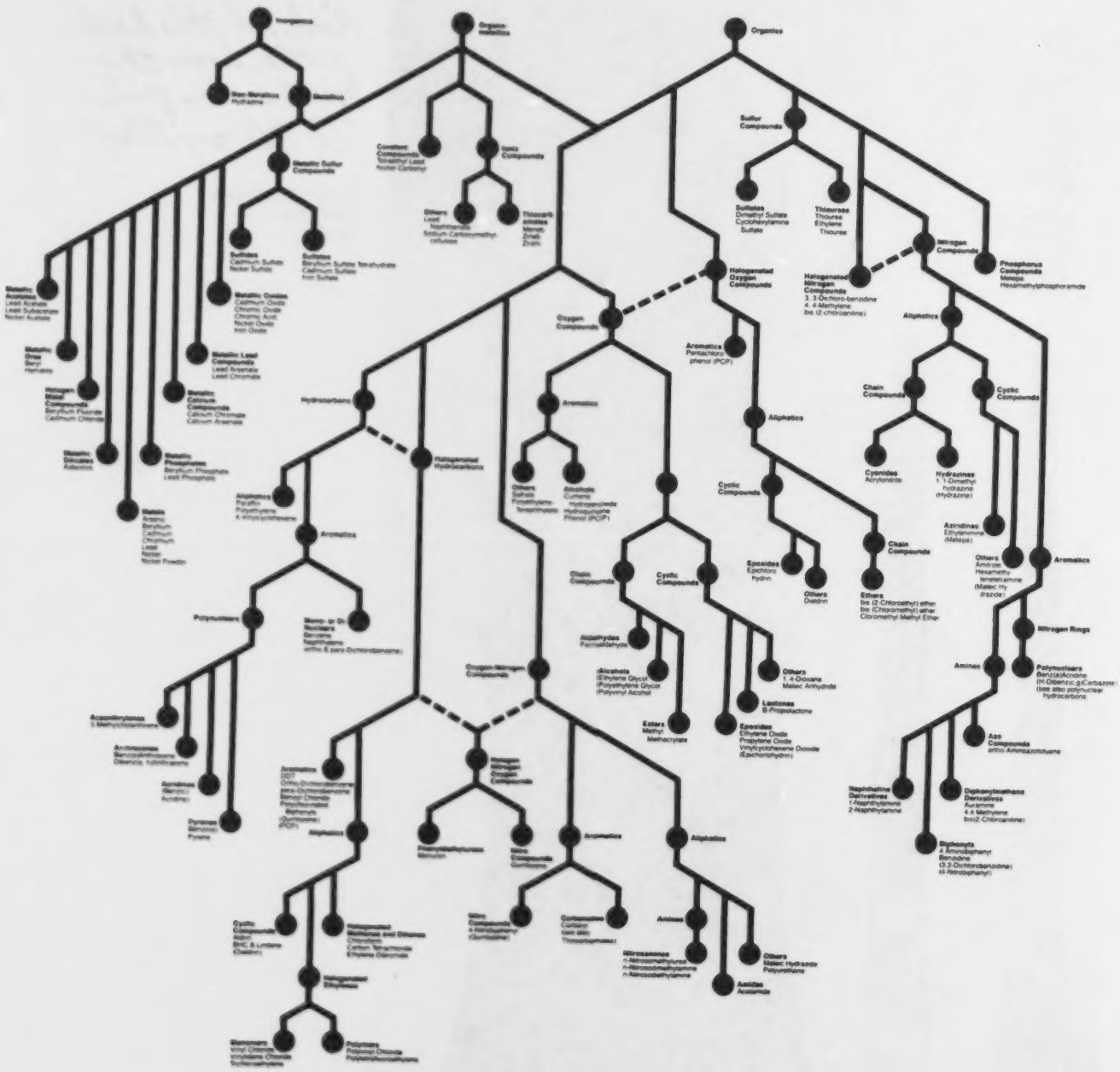
Identify human exposure. To protect humans from toxic substances we should identify the type of substances in the environment and quantify the level of exposure currently encountered. To do this, we will have to conduct many tests to identify toxic substance residues and metabolites in human and animal tissues. Since people are exposed to toxic substances via many routes, we must obtain chemical analyses of samples from all of those environments—indoor, outdoor, automobile, etc.—which people frequent.

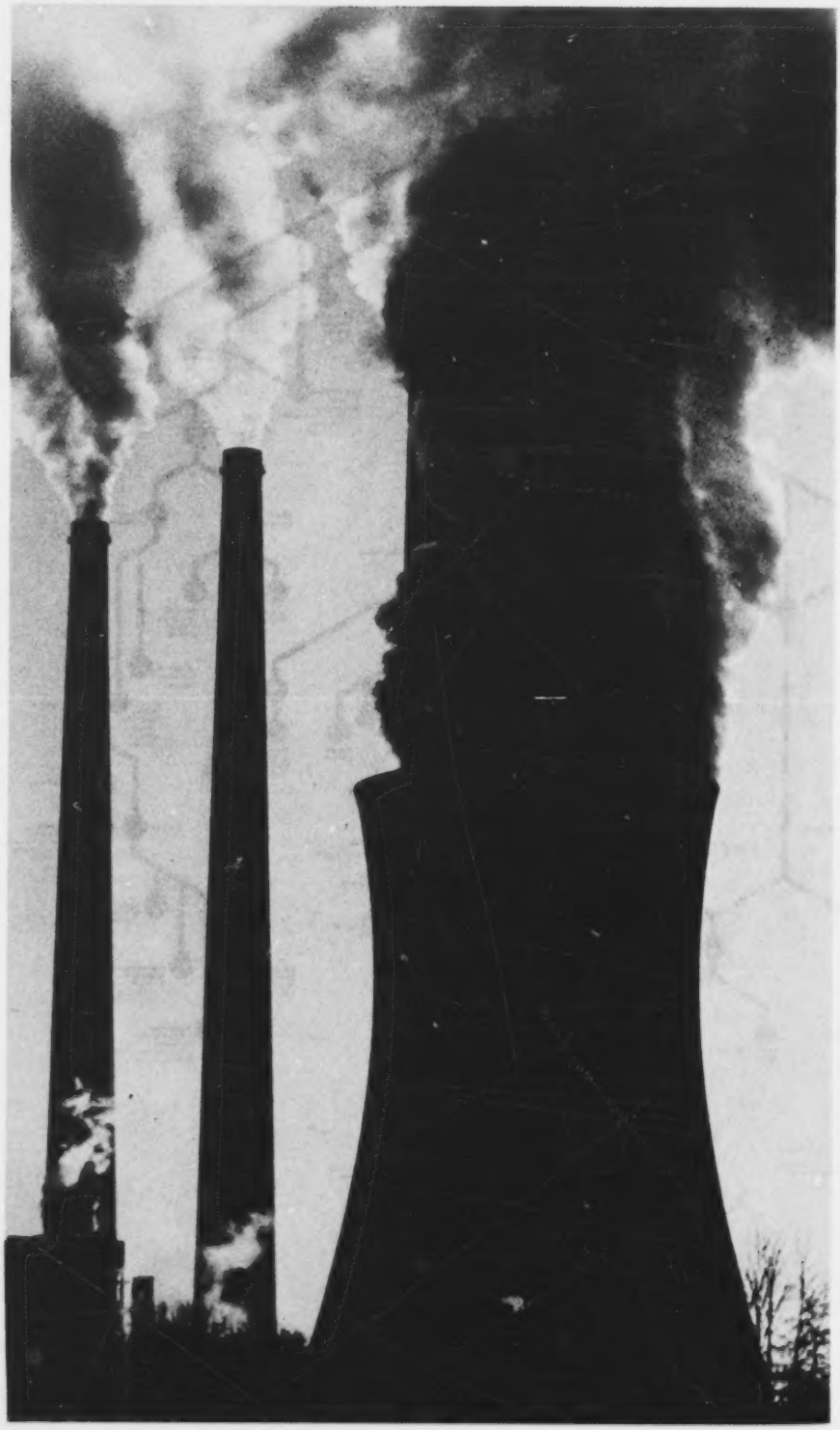
The effects of exposure to environmental chemicals on human development, aging, and behavior should also be better understood. Damage during the stages of human development from prenatal to old age may result in irreversible effects. Short-term tests are needed to determine the influence of toxic chemicals in developmental and degenerative diseases.

Identify improved control methods. Given the ability to identify toxic levels of pollutants and to trace them back through the ecosystem—the air, water and food we use—to their sources, we can then begin to control the sources. Where current technologies either fail to control certain substances or create secondary pollutants of their own, we will have to go further. For example, many wastewater treatment technologies now in use fail to remove toxic metals to an adequate degree. Improved control technologies such as sulfide precipitation should be developed to reduce the discharge of such metals. Other alternatives, such as changing the processes which produce the pollutant, should also be developed. For example, electroplating processes which do not require cyanide or hexavalent chromium (two highly toxic substances) should be investigated.

Once a toxic substance has been released and has contaminated the environment, other approaches must be used to limit human exposure. For example, some toxic metals and organic chemicals may settle and concentrate in river bottoms, in soils adjacent to manufacturing facilities, and in poorly designed or managed landfills. Further research is necessary into methods to contain, detoxify, or recover for recycling such materials from their current hazardous state in the environment.

Potential Chemical Carcinogens


Inorganic
Organic Metallics
Organics
Non-Metallics Hydrazine
Metallics
Metallic Sulfur Compounds
Sulfides Cadmium Sulfide Nickel Sulfide
Sulfides Beryllium Sulfide ferrocyanide Cadmium Sulfide Iron Sulfide
Metallic Oxides Cadmium Oxide Chromic Oxide Chromic Acid Nickel Oxide Iron Oxide
Metallic Lead Compounds Lead Arsenate Lead Chromate
Metallic Chloride Compounds Calcium Chromate Calcium Arsenate
Metallic Phosphate Beryllium Phosphor Lead Phosphate
Metallic Arsenic Beryllium Cadmium Chromium Lead Nickel Nickel Powder
Metallic Carbonyl Compounds Nickel Carbonyl
Ionic Compounds
Others Lead Trichloroethylene Sodium Carboxymethyl cellulose
Thiourea Diethyl Ethyl Thiourea
Sulfur Compounds
Sulfates Dimethyl Sulfate Cyclohexylamine Sulfate
Thioureas Thiourea Ethylene Thiourea
Nitrogen Compounds
Phosphorus Compounds Mexaps Hexamethylphosphoramide
Halogenated Oxygen Compounds
Halogenated Nitrogen Compounds 3, 3-Dichloro-benzidine 4, 4-Methylene bis (2-chloroaniline)
Oxygen Compounds
Aromatics Pentachloro phenol (PCP)
Aliphatics
Chain Compounds
Cyclic Compounds
Cyanides Acrylonitrile
Hydrazines 1, 1-Dimethyl hydrazine (Hydrazine)
Hydrocarbons
Halogenated Hydrocarbons
Aromatics
Others Safrole Polychlorinated biphenyls
Alcohols Cumene Hydroperoxide Hydroquinone Phenol (PCP)
Aliphatics
Polycyclic Polyethylene 4-Vinylcyclohexene
Aromatics
Cyclic Compounds
Chain Compounds
Epoxides Epichloro hydrin
Others Dieldrin
Chain Compounds
Ethers bis (2-Chloroethyl) ether bis (Chloromethyl) ether Clorometyl Methyl Ether
Azaridines Ethylenimine (Meleze)
Others Amiprole Hexamethylenetetramine (Maleic Hydrazide)
Aromatics
Polycyclics
Nitro- or Di-Nitro- Isomers Benzene Naphthalene ortho, & para-Dichlorobenzene)
Acetaldehyde Formaldehyde
Alcohols (Ethylene Glycol (Polyethylene Glycol (Polyvinyl Alcohol
Others 1, 4-Dioxane Maleic Anhydride
Lactones B-Propiolactone
Esters Methyl Methacrylate
Epoxides Ethylene Oxide Propylene Oxide Vinylcyclohexene Dioxide (Epichlorohydrin)
Nitrogen Rings
Amines
Polynuclears Benz(a)Acridine (N-Oberon)c g)Carbazole (see also polynuclear hydrocarbons
Azo Compounds ortho-Aminoazotoluene
Naphthalene Derivatives 1-Naphthylamine 2-Naphthylamine
Diphenylmethane Derivatives Auramine 4,4-Methylene bis(2-Chloroaniline)
Diphenyls 4-Aminodiphenyl Benzidine (3,3-Dichlorobenzidine) (4-Nitrodiphenyl)
Pesticides DDT Ortho Dichlorobenzene para-Dichlorobenzene Benzyl Chloride Polychlorinated Biphenyls (PCB's)
Aromatics
Polycyclic Aromatic Hydrocarbons Benzo (a) Pyrene Coal Tar Pitch Creosote Carbazole
Phenanthrene Benzene
Nitro Compounds Quinoline
Aromatics
Aliphatics
Cyclic Compounds Aldrin Dieldrin BHC & Lindane Chlordan
Halogenated Methane and Ethane Derivatives Chloroform Carbon Tetrachloride Ethylene Dibromide
Halogenated Ethylenes
Monomers Vinyl Chloride Vinylidene Chloride Trichloroethylene
Polymers Polyvinyl Chloride Polytetrafluoroethylene
Amines
Nitrosamines n-Nitrosomethylurea n-Nitrosodimethylamine n-Nitrosodiethylamine
Others Maleic Hydrazide Polyurethane
Azo Dyes Aminoazobenzene



Absent thee from felicity awhile,
And in this harsh world draw thy breath in pain,
To tell my story.

William Shakespeare
1564-1616
Hamlet

Air pollution

Goals

The goals of the national air pollution research efforts are to improve our understanding of the formation and transport of atmospheric aerosol pollutants, the potentially serious risks that these aerosols present to the public health and the environment, and the possible alternatives for reducing human exposures to these pervasive pollutants.

Atmospheric aerosols will likely preoccupy much of the attention of the nation's scientists who conduct research on air pollution. We have, during the past two decades, developed reasonable confidence in our understanding of how the major gaseous pollutants such as carbon monoxide, sulfur oxides, nitrogen oxides, and ozone are formed and how they affect human health. We also know that these gases react chemically in the "chemical soup" of the atmosphere, often to form aerosols. We are now focusing increased effort on the complex of the secondary (formed in the atmosphere) aerosols which are found in the air throughout the country.

Because of the apparent complexity of the atmospheric chemistry involved, we cannot fully characterize these aerosols. We do know that they are fine bits of matter, often containing solids, liquids, and gases at the same time. We also know that the gaseous pollutants, especially sulfur and nitrogen oxides, are important chemical precursors to these aerosols. A simplified view of one set of reactions which occur is that the sulfur and nitrogen oxides are oxidized in air and react with water to form acids which, in turn, react with metallic particulate pollutants to form complex sulfates and nitrates. If the polluted air mass is involved in precipitation, the water-soluble acids may appear in the rain or snow. Of course, few things in nature are that simple, especially when reactive hydrocarbons and the photochemical oxidants which they produce are added to the mixture.

The result of our improved understanding of the complex interactions in the atmosphere is that we must continue to focus on providing adequate control of the sources of the gaseous pollutants—power plants, industrial plants, automobiles, and trucks. At the same time, we must sharpen our understanding of what the reaction products are, where they go, and how they affect people, agricultural crops, forests, and the natural environment.

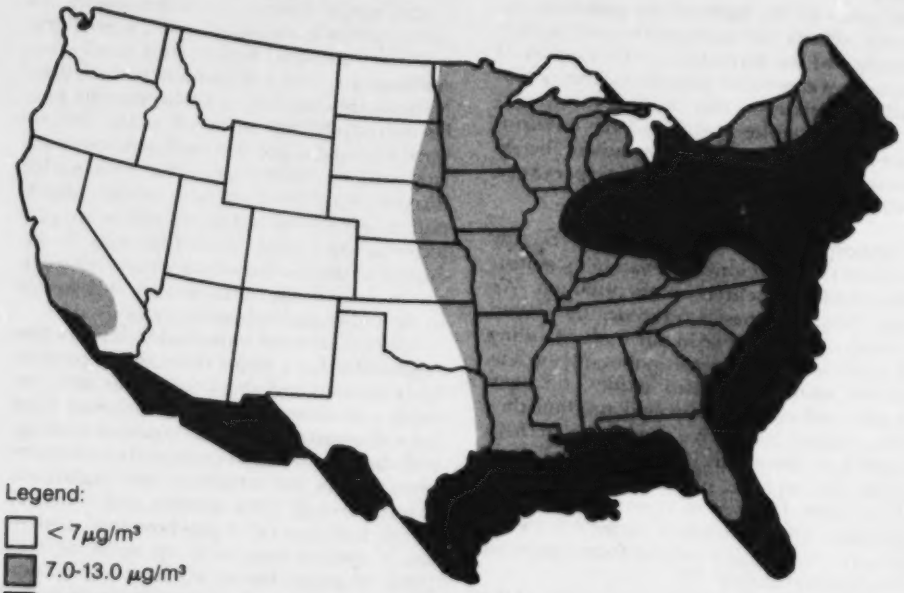
Sources and trends

The major sources of sulfur oxides are power plants burning coal with high sulfur content. Industrial boilers and nonferrous smelters are other important contributors. Nationwide emissions of sulfur dioxide have been dropping due primarily to the shift toward oil, natural gas and coals with lower sulfur content. However, even with sulfur dioxide scrubbers on new power plants, nationwide sulfur dioxide emissions are projected to rise during the next 12 years. As discussed in the *Environmental Futures* chapter, this increase is due to the massive shift to coal in the utility and industrial sectors.

Power plants and industrial boilers are also responsible for a major share of the particulate emissions and about half of the nitrogen oxide emissions. Particulate emissions have been dropping and should continue to drop, with the installation of improved electrostatic precipitators, wet scrubbers, and baghouses, at least through 1985. Because coal is a much dirtier fuel than oil or gas, however, particulate emissions may turn up again beyond 1985, meaning that we will have to continue to investigate the role of particles in air pollution chemistry and health effects. As far as air pollution chemistry is concerned, it appears that the fine particles (those smaller than three microns) are more likely to be involved in chemical reactions. These small particles are also more likely to be direct causes of respiratory problems because they can be inhaled deeply into the lungs. Further, recent work has indicated that some of this fly ash gives positive results in the Ames screening tests for mutagenicity. Unfortunately, currently used precipitators and scrubbers allow many of the fine particles to escape.

Nitrogen oxide emissions, which come from the combustion of fossil fuels and are split evenly between transportation and boiler sources, have leveled off in recent years due to the economic slowdown and automotive control measures. Unfortunately, projections indicate that nitrogen oxide emissions are beginning to grow again and may be up 25 percent by 1985. Although some of the immediate increase is due to delays in applying more stringent controls on automobiles, the overriding factor in the increase is the growth in the utility sector and the shift in that sector toward coal. Coal-fired boilers release three to six times as much nitrogen oxides as do oil and gas-fired boilers. Unfortunately, there are not now at hand control techniques to reduce markedly the nitrogen oxides from coal-fired boilers, although certain combustion modification techniques are

Urban Sulfate Concentrations



Legend:

- < 7 μg/m³
- 7.0-13.0 μg/m³
- > 13.0 μg/m³

Nonurban Sulfate Concentrations

Legend:

- < 1.0 μg/m³
- 1.0-2.9 μg/m³
- 3.0-6.9 μg/m³
- 7.0-9.0 μg/m³

Source: U.S. Environmental Protection Agency, 1975.

showing great promise in early laboratory tests.

Carbon monoxide and hydrocarbons, which come primarily from incomplete combustion in car and truck engines, have been decreasing and will continue to do so with the application of the catalytic converters. Hydrocarbon emissions from fugitive industrial sources (such as evaporation, leaks, and spills) may turn out to be a problem in some areas.

The potentially rapid penetration of diesel-powered cars and light trucks into the United States market—up to 25 percent by 1990—raises another problem which must be considered in this context (Ref. 1). Relative to automobiles equipped with catalysts, light-duty diesel engines would emit much more fine particulate matter (diesel soot) which consists of unburned hydrocarbons and the products of partial combustion attached to micron-scale particles of carbon. EPA research has indicated that some of the products give positive results in the Ames tests for mutagenicity.

Taken altogether, these developments indicate that, while progress is being made in controlling some air pollutants, projected growth in other air pollutants coupled with our expanded knowledge of atmospheric transformation and transport raises serious concerns about regional air quality degradation and the associated health effects. These trends help to focus our attention on the problems of widespread secondary, especially aerosol, air pollution.

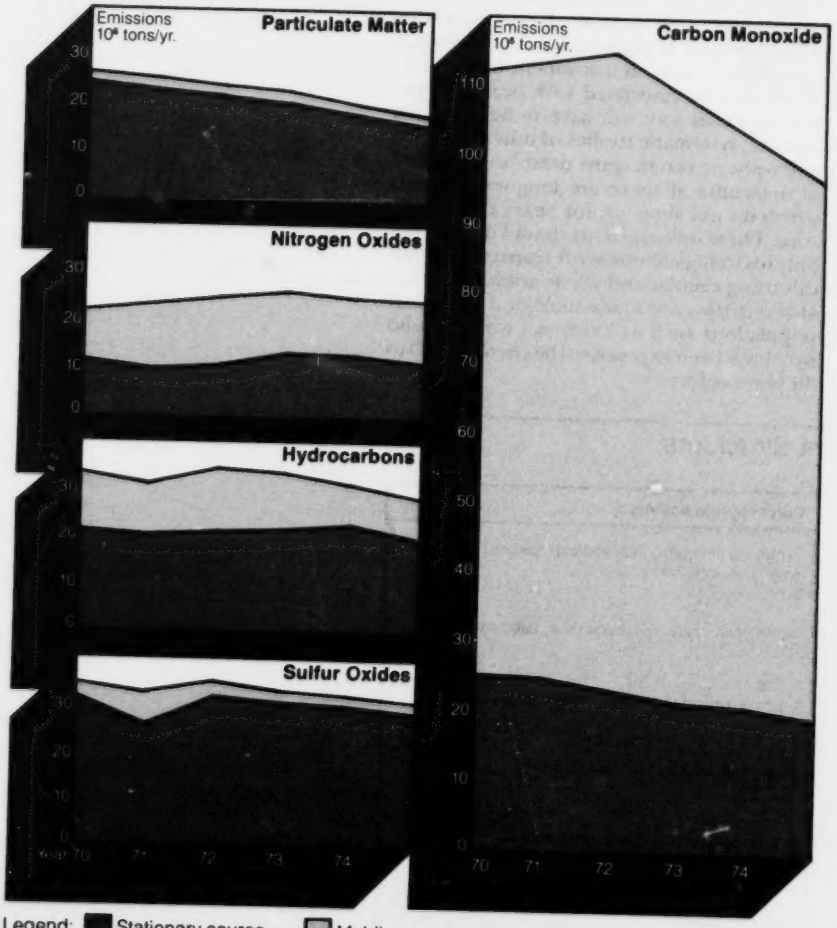
We are already concentrating on the complex relationship between sulfur dioxide emissions and atmospheric sulfates. Recent field studies by EPA indicate that sulfur dioxide in power plant plumes is converted to sulfates over long distances (100 to 500 kilometers). Thus, the effect of sulfur dioxide pollution may be felt over a broad area.

Recent measurements of sulfate concentrations give general support to this observation. Sulfate concentrations in cities east of the Mississippi tend to be high, with the highest readings recorded in cities lying in a band from New York to Chicago. While sulfate concentrations in rural areas are typically somewhat lower, they are considerably elevated across the eastern half of the country, with the Mid-Atlantic and industrial Midwest most affected. In fact, when weather patterns are taken into account, the areas with the highest rural sulfate concentrations appear to be 'downwind' from the most intense urban and industrial sources of sulfur dioxide.

Although sulfate concentrations west of the Mississippi River are relatively low, the effect of the sulfate aerosol on visibility in that region has become a major issue. One of our most important recent discoveries is that the atmospheric particles in the size range of 0.1 to 1.0 micron are largely responsible for light scattering and, thus, for visibility degradation. With the rapid growth of coal-fired power plants which is projected for the West, there is a real potential for decreased visibility, in the vicinity of national parks and other scenic vistas, due to sulfates and fine particles coming from coal combustion.

One recent graphic example of the effect of sulfates on visibility involves another important source of sulfur oxides in the Southwest. During a strike at copper smelters in the Southwest, the smelters were shut down for

Air Pollutant Emission Trends



Source: U.S. Environmental Protection Agency, 1976.

nine months. As a result, sulfate levels were 38 to 75 percent below seasonal averages. Visibility measurements at airports in the region improved by 5 to 25 percent.

There is also growing evidence that nitrogen oxides and photochemical oxidants may be following the same general trend—conversion and transport over considerable distance. Recent studies have indicated that nitrogen oxides may be emerging as an important precursor to nitric acid which is increasingly showing up in precipitation in New England, far from the dominant combustion sources in the industrial Midwest.

We must improve our understanding of the dynamics of transport and transformation of the atmospheric aerosol and fine particulate complex. Field studies should be expanded to improve our knowledge of how sulfur and nitrogen oxides are oxidized to acidic chemicals and how other atmospheric pollutants interact with them in the aerosols.

Effects on health

The aerosol complex may have more serious effects on human health than the sulfur and nitrogen oxides in gaseous form. Nitrogen dioxide has been associated with acute effects in sufferers of respiratory disease, even for short exposures, while sulfur dioxide has been associated with asthma attacks. More serious problems may result from exposure to the fine aerosols and particles since they penetrate deeply into the air sacs (alveoli) of the lungs.

We must expand our toxicological, clinical, and epidemiological studies to better understand the effects of the aerosols. Continued attention must be focused on the acute effects of the aerosols in the respiratory system. In addition, it is essential to rapidly expand investigations on other potential effects—both chronic and acute—which may result from aerosols. If the aerosols carry harmful, including carcinogenic, materials into the lungs the long-term consequences could be much more serious.

Carcinogenicity has been associated with some organic compounds, especially some polycyclic and heterocyclic hydrocarbons, which have been found in the atmosphere. As mentioned before, organic compounds adsorbed on the carbon particles in diesel exhaust have exhibited positive mutagenic effects in the Ames screening test. These substances may prove to cause cancers in animals which are now being subjected to inhalation tests. If so, a careful assessment of the risks which may be associated with human exposure to diesel soot will have to be made. In parallel, systematic studies of other potential atmospheric carcinogens must be expanded to determine if there are long-term effects which do not show up for years after exposure. These investigations should include not only toxicological studies of suspected chemicals using cellular and whole animal tests but also retrospective epidemiological studies of populations such as industrial workers who may have been exposed to the chemicals 20 to 30 years before.

Examples of Carcinogenic Air Pollutant Structures

Compound	Structure	Carcinogenic Activity
Benzo (a) pyrene		Highly carcinogenic in animals (9 species) (oral, skin, intratracheal)
Chrysene		Weakly carcinogenic in mice (skin, subcutaneous)
Benzo (b) fluoranthene (Benz (e) acephenanthrylene)		Carcinogenic in mice (skin, subcutaneous)
Indeno (1,2,3-cd) pyrene		Highly carcinogenic to mice (skin)
Dibenz (a, h) acridine		(Carcinogen in mice (skin, subcutaneous)
Dibenz (a, i) acridine		Very weakly carcinogenic in mice (skin, subcutaneous)

Source: Kornreich, M. R., 1975.

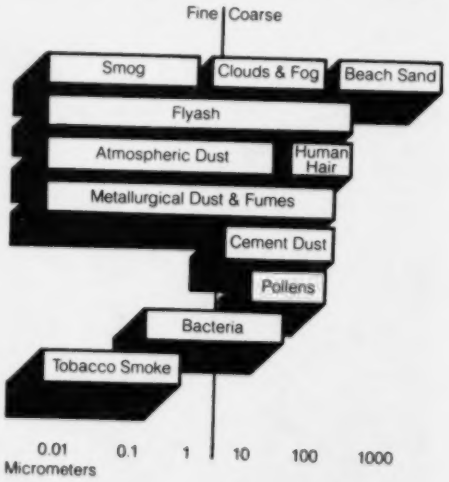
Controlling aerosol sources

Because they are formed largely in the atmosphere, aerosols are going to present a more complex control problem. The approach taken to date has been simply to control, as well as possible, the major precursors to the aerosols—sulfur and nitrogen oxides, hydrocarbons, and particulates. While this may be adequate in most cases, serious health threats from certain aerosols may require more restrictive control measures.

Diesel soot may represent one of these cases. Changes in the engine design or operating conditions may give adequate reductions; control devices may also be required. But this represents a more classical case—potential for enhanced control at the source.

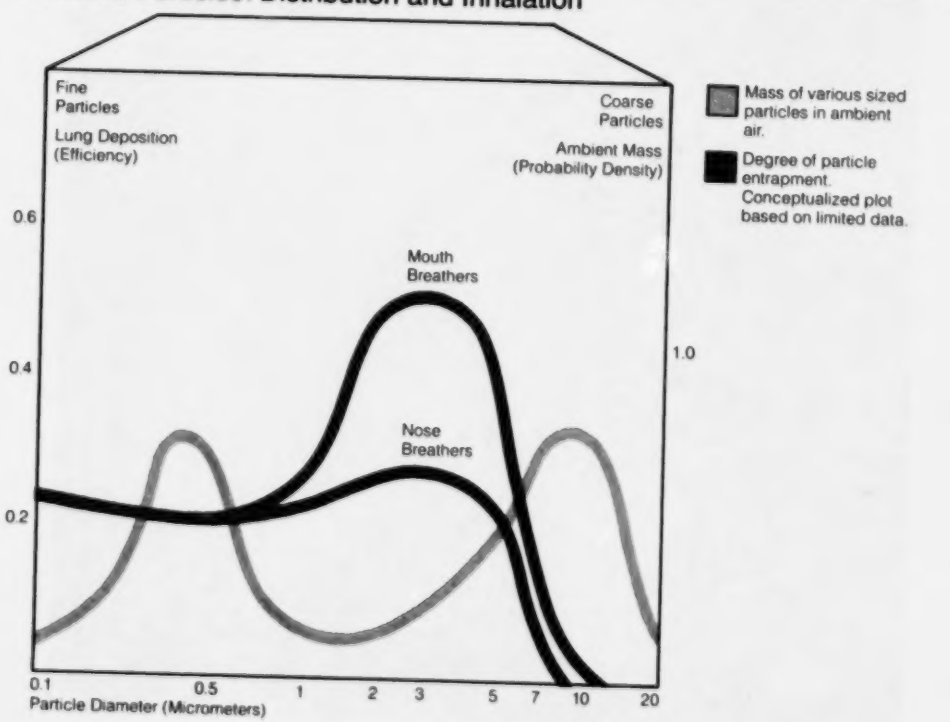
Two other situations may also arise to challenge our ingenuity and engineering skills. If industrial hydrocarbons are found to interact in the atmosphere to produce carcinogens, then it may be necessary to tighten up controls on fugitive emissions of the more dangerous precursors. If the long-term effects of metallic sulfates and nitrates turn out to be serious, then control measures for sulfur and nitrogen oxides may be required. Alternative control strategies will have to be carefully considered because of the serious economic implications of such steps.

Sizes of Typical Airborne Particles



Source: U.S. Environmental Protection Agency, 1977.

Airborne Particles: Distribution and Inhalation



Coal is a portable climate.

Ralph Waldo Emerson
Conduct of Life (1860)

Energy and the environment

Goals

The goals of the national energy-related environmental research and development efforts are to understand the health and environmental impacts which could result from increased domestic energy production and use and to take the steps required to protect public health and the natural environment. These goals encompass our domestic energy resources (coal, oil, gas, nuclear, solar, geothermal, etc.) and both existing and new methods for energy processing and conversion.

Availability of affordable energy became a serious national concern in the wake of the energy crisis of 1973. Uncertainties in reliability of energy supply, growth rates, fuel prices, and pollution control requirements created a climate of conflict among many interest groups, especially between those favoring either energy development or environmental protection. The development of the National Energy Plan and strong Presidential and Congressional commitment to environmental protection now offer a framework for reconciling the differences between development and protection interests.

Although the National Energy Plan seeks to reduce the rate of energy consumption through energy conservation, energy use in the United States is still expected to increase by two-thirds between now and the year 2000 (Ref. 1, 2). Dominating this trend would be electric power generation using coal and nuclear energy. Other energy sources, such as oil shale and geothermal energy, would come into play with associated potential for environmental degradation. Gaseous and liquid fuels derived from coal would pick up part of the supply shortfall for transportation and residential uses. Finally, use of renewable resources such as solar and wind energy could offer some dramatic environmental benefits.

EPA plays a major role in Federal energy-related environmental research and development, both as coordinator of the $100-million-per-year Interagency Energy/Environment R&D Program and through its own resarch into health effects, environmental impacts, and control techniques of energy systems. Since this research program was initiated in 1975, our major focus has been on assessing—and mitigating—the effects of increased coal use.

Energy extraction

Coal mined in the United States may nearly double by 1985 and triple by the year 2000 (Ref. 3). Clearly, if major environmental damage is to be avoided, environmental problems created by such mining must be identified and suitable control techniques required.

For coal mining in Appalachia, many environmentally protective measures have been developed. The new Surface Mining Control and Reclamation Act will accelerate use of these techniques. Assessments of the degree of the environmental protection afforded by these approaches must be carried out. One remaining problem is the characterization and control of toxic materials in mine drainage and runoff. Another major, and possibly intractable, problem is the control of acid mine drainage from closed underground mines.

Western coal mining, on the other hand, represents a more difficult situation because of the low rainfall, high winds, erosion potential, and the delicate balance of the surface and groundwater regimes in western mining locations. Rapid growth of mining in the West, without adequate protection, could threaten the integrity of fragile ecosystems, groundwater aquifers, and air and water quality. It is important that research efforts continue to keep pace with coal development in that region and that new information and techniques be quickly applied to enhance environmental protection.

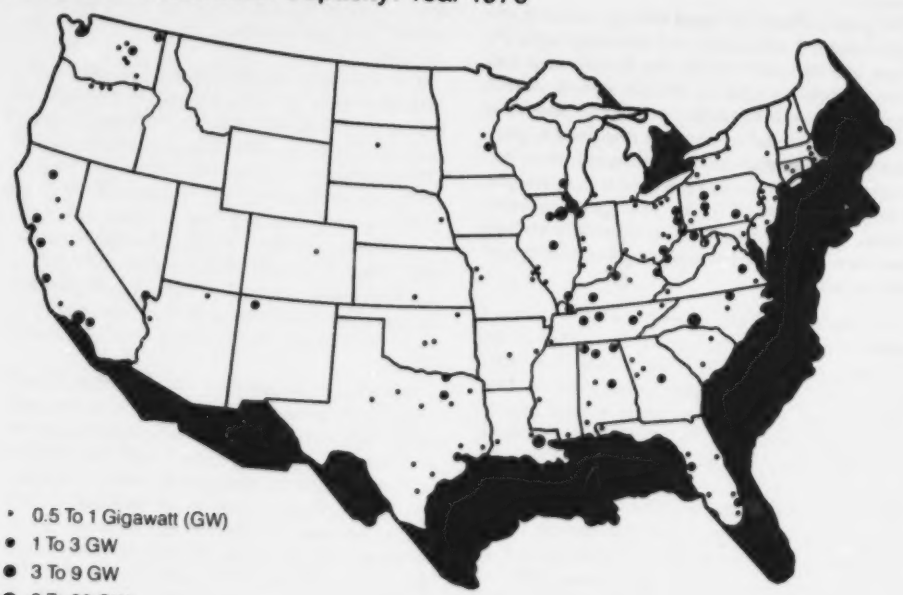
Other energy resources produced by surface mining activities in the West include oil shale and uranium. Both mining—and the associated processing steps—can lead to contamination of surface and groundwater. Special problems include runoff from spent shale landfills and solvents used in leaching uranium. Both of these problems require special research attention.

Conventional combustion

The National Energy Plan calls for the expansion of annual coal use from the current 635 million metric tons to more than 900 million metric tons by 1985, with the massive increases coming primarily in the utility and industrial sectors. The strong emphasis on conservation in the Plan and the application of stringent environmental controls will tend to minimize environmental degradation, but with such large increases in coal uses emissions of nitrogen and sulfur oxides from coal combustion are projected to rise above current levels by 1985. With increased fossil fuel combustion, CO_2 emissions will increase accordingly. The chapter on *Global Pollution* addresses the CO_2 buildup problem.

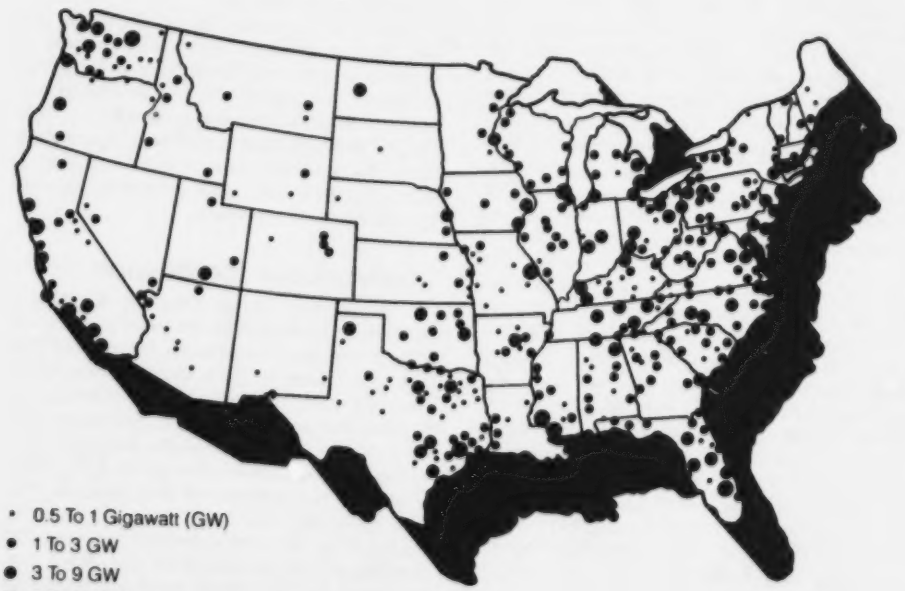
As a result of the Clean Air Act amendments of 1977, EPA is currently revising

Electrical Generation Capacity: Year 1970



- 0.5 To 1 Gigawatt (GW)
- 1 To 3 GW
- 3 To 9 GW
- 9 To 20 GW

Year 2000



- 0.5 To 1 Gigawatt (GW)
- 1 To 3 GW
- 3 To 9 GW
- 9 To 20 GW

Source: Council on Environmental Quality, 1976.

Energy Supply Projections

Energy Source	1975	1985		2000	
		Plan**	Pre-Plan	Plan	Pre-Plan
Coal	15.3*	28.2	23.9	44.9	38.0
Domestic Oil	20.7	21.8	18.7	17.9	18.0
Oil Shale		.3	1.1	2.9	3.0
Oil Imports	12.8	13.3	24.3	13.0	28.2
Domestic Gas	18.6	17.6	17.8	15.4	14.2
Gas Imports	1.0	1.8	3.0	1.1	3.4
Nuclear	1.8	7.6	7.4	18.7	25.0
Solar (except Biomass)		.2	.1	1.8	1.4
Geothermal		.3	.2	2.7	2.5
Hydropower	3.0	3.1	3.1	3.6	3.6
Biomass				1.5	1.5
Total	73.2	94.2	99.6	123.5	138.8

Notes:
* Data expressed in Quads
**The National Energy Plan

Plan Source: U.S. Energy Research and Development Administration, 1977.

Utility and Industrial Combustion Problems

Pollutant	Present Standard	Control Technology	Status	Secondary Residuals	Needed Research
Sulfur Dioxide	New Source Performance Standards and Ambient Air Quality Standard (health-related)	Coal cleaning	First generation demonstration	High-sulfur refuse	Eliminate secondary pollution Demonstrate practicability Broaden applicability
		Flue gas desulfurization	First generation in full scale demonstration Second generation in bench and/or pilot scale	Sludge, purge streams	Eliminate secondary pollution Improve reliability Broaden applicability Improve energy efficiency
Nitrogen Oxides	New Source Performance Standards and Ambient Air Quality Standard (health-related)	Combustion modification	Commercial for some new units	Possibly more particulates and carbon monoxide	Broaden source applicability Improve energy efficiency Improve nitrogen oxides control efficiency (only 30% for combustion modification) Minimize impact of residual pollution
		Flue gas treatment	Pilot scale and demonstration in Japan	Varies with process	
Particulates	New Source Performance Standards and Ambient Air Quality Standard (health-related)	Electrostatic precipitators	Commercial	Fly ash	Improve cost-effective fine particulate matter control Broaden applicability Develop novel devices with improved capability
		Baghouses	First generation demonstration		
		Wet scrubbers	First generation commercial, second generation full scale demonstration		
		Novel devices	Bench or pilot scale		
Hazardous Materials		Undefined	Undefined	Undefined	Problem requires definition

Source: Princiotta, F. T., 1977.

Energy Technologies

Technology	Status	Environmental Concerns
Gasification	Low-energy process in use in Europe. High-energy process to be available in the 1990s.	On-site subsidence. Air and water contamination.
Liquefaction	Solvent refined coal process near commercialization. Availability of other processes expected about 1990.	Air and water contamination.
Fluidized-Bed Combustion	Pilot plants being tested. Availability expected in the 1990s.	Thermal pollution. Disposal of spent sorbent. Air and water contamination.
Oil Shale	Pilot plant in operation. Availability of surface and in situ processes expected in 1985.	Disposal of overburden and spent shale. Air and water contamination.
Nuclear Fission	In use. Plutonium reprocessing, waste solidification, and potentials for armament proliferation under study.	Radioactive waste disposal. Water contamination. Thermal pollution.
Fusion	In early testing stage. A 21st century technology.	Decommissioned reactors. Radioactive wastes.
Geothermal	In use. Increased application expected in the 1990s.	Subsidence. Noise. Air and water contamination. Thermal pollution.
Solar	Heating of buildings commercialized. Cooling of buildings and biomass fuels expected in the 1980s. Availability of thermal electric technology project for the 21st century. Demonstration of Ocean Thermal Energy Conversion expected by 1985. Production of clean fuels from biomass, post-1990.	Toxicity of working fluids. Land and water use. Climatic change. Marine pollution.

emission standards for coal-fired power plants. These standards are likely to require improved control of sulfur dioxide, nitrogen oxides, and particulates. Also, EPA anticipates establishing standards for industrial boilers. However, higher efficiency, lower-cost control technologies may be required for utility and industrial combustion facilities. This is especially true for nitrogen oxides. Fortunately, EPA research has recently shown that nitrogen oxides from combustion can be reduced by as much as 80 percent by "combustion modifications" (lowering the combustion temperature, limiting the amount of oxygen available, and regulating the way the fuel and air mix) in the boiler.

Fundamental research on the chemical and aerodynamic mechanisms involved in combustion can help us understand how nitrogen oxides are formed and how they may be controlled without increasing emissions of other pollutants. Research into new low nitrogen oxide designs for combustion equipment, alternative fuels, and advanced combustion concepts may make it possible to burn coal cleanly and more efficiently during the next decade. EPA must work closely with the Department of Energy and the private sector to advance such approaches and to assure that other less understood problems (e.g., emissions of trace elements and polycyclic organic materials) are not overlooked.

Emerging energy technologies

To lessen the nation's dependence on petroleum and natural gas, the Department of Energy has launched a multibillion dollar technology research, development, and demonstration program. Substantial funds are also being expended in this effort by the private sector. Receiving major emphasis are technologies which will facilitate the use of abundant fossil fuels such as fluidized bed combustion of coal, the conversion of coal into synthetic liquid and gaseous fuels, and *in situ* retorting of oil shale. Without proper controls, such emerging energy technologies could threaten public health and the environment. In many cases these technologies produce pollutants quite different and potentially more harmful than those generated by current generation coal-fired boilers. The development efforts must be accompanied by careful monitoring of available pilot and demonstration facilities by EPA researchers. Concurrently, we need to evaluate the adequacy of available control technology.

Assessments of the environmental impacts of geothermal and renewable resource technologies are also required to avoid future problems.

Finally, determination of exposures to, and effects of, energy-related pollutants on human health is necessary to establish ambient and emission control standards to protect public health. Knowledge of aquatic and terrestrial impacts of energy use is also necessary to set criteria which will protect the natural environment.

To waste, to destroy, our natural resources, to skin and exhaust the land instead of using it, so as to increase its usefulness, will result in undermining in the days of our children the very prosperity which we ought by right to hand down to them amplified and developed.

Theodore Roosevelt
1858-1919
Message to Congress, 1907

Solid waste

Goals

The goals of the solid waste research effort are to determine the risks associated with the handling and disposal of toxic solid waste and to develop means of adequately protecting public health by isolating the toxic materials from the environment, detoxifying the wastes before disposal, or recovering the energy and mineral content of the waste for recycling.

In the United States, we are now producing over five billion metric tons of solid waste* each year. This waste is expected to increase substantially over the next two decades, as pointed out in the *Environmental Futures* chapter. Further, as the projections indicate, all types of solid waste will increase. This can be easily understood when we consider that a rapidly increasing proportion of the waste materials which once were dumped into the air and water are now being controlled and converted to solid or semisolid forms such as sludges.

Of concern are the hazardous materials in industrial solid wastes. This now amounts to 10 to 30 million metric tons (dry weight) annually (Ref. 1), an amount that will increase by 30 percent within the next 15 years (Ref. 2).

Public health is directly affected by the disposal of solid waste (Ref. 3). The traditional dumps and open landfills—to be prohibited under the Resource Conservation and Recovery Act—have served as breeding grounds for rats, flies, and other disease carriers. Leachate from landfills often contains high concentrations of organic and inorganic materials that can seriously pollute surface and groundwater. The use of landfills for disposal of industrial wastes containing hazardous materials heightens immensely the concern for adequate environmental protection measures. Recent studies have revealed that some of these hazardous wastes have been inadequately disposed of and are leaking, in high concentrations, into areas where people may be exposed.

The current Agency strategy places the highest priority on development of disposal technology and management criteria for hazardous and industrial wastes, followed in turn by wastewater treatment sludges, municipal solid waste, and mining and agricultural wastes.

* Solid waste results from consumer activities, industrial processes, the harvesting of crops and forests, and the development of mineral and energy resources. It also results from efforts to abate air and water pollution.

Resource conservation and recovery through in-plant process changes, recycling, and waste exchange offer important alternatives to our traditional patterns of waste management. Since the potential energy and resource savings from recovering wastes may be significant, such efforts now have high national priority. Exchange of wastes between two or more waste generating plants may, in some cases, offer an innovative solution such as waste neutralization or production of beneficial byproducts.

Mining waste causes environmental damage, although such waste is often generated in remote areas and does not generally cause health problems. Notable exceptions include severe localized problems created by poor disposal practices for radioactive materials and coal washing waste.

Waste from agricultural and forestry activities, especially when concentrated and improperly managed, can result in runoff of large quantities of dissolved and solid materials into surface waters, thereby seriously degrading water quality. In some watersheds, nutrients in such runoff can be the major cause of eutrophication. Runoff of pesticide contaminants can also pose hazards to animals and humans. Thus, disposal practices for agricultural and forestry wastes are closely linked to the broader problem of controlling water pollution from nonpoint sources.

The variety of problems confronted in dealing with solid waste makes it difficult to generalize. One source may require recycling and reuse. Another may require treatment technology, while still others may have to follow Best Management Practices.

Industrial solid wastes

Of the five to ten percent of industrial wastes which are potentially hazardous, over 90 percent are inadequately managed at present (Ref. 2). Growth trends indicate that the amounts of potentially hazardous wastes will increase by over 30 percent in the next decade, due largely to the wider use of air and water pollution control equipment (Ref. 2). At present, only two percent of potentially hazardous waste is recovered (Ref. 1), but there appears to be a potential for recovery of several scarce metals. As the quantity of hazardous waste increases, the need for recycling and other advanced waste management technologies will become increasingly important. Careful attention witl have to be given to the more than 90 percent of waste now inadequately managed.

Municipal wastewater sludge

Sludges from municipal wastewater treatment plants will double over the next 15 years. The composition of municipal sludges now varies widely from city to city, depending on the local mix of commercial and industrial activities. How the composition will change in the future depends on a number of local control decisions, which will affect the contamination of sludge with metals, organic wastes, pesticides, etc. One contaminant of current concern is cadmium, especially if the sludge is to be applied to land. If cadmium enters the human food chain, it may be accumulated in the liver and kidneys. Other metals of concern in sludge include copper, molybdenum, mercury, lead, and selenium, although these metals are usually found in much lower concentrations.

In addition to metals, some pathogenic bacteria and viruses show up in the sludge. Although some bacteria do not appear to present a health risk because they die when exposed to the environment, some viruses persist for long periods in some soils and may move into surface or groundwater. The extent, if any, of this threat must be determined.

In addition to disposal by land application, sewage sludge may be combusted to reduce significantly the solids while producing heat. Since some sludge has high levels of toxic substances, it is necessary to know the concentration of these substances in both the air and residual discharge streams. Techniques, such as pretreatment of industrial wastes before mixing with the municipal wastewater streams, may be required to reduce toxic substances in the sludge to lower the possibility of secondary pollution.

Residential, commercial, and institutional waste

Municipal solid waste contains the discards of both the residential and commercial sectors, including such potentially hazardous materials as pesticide containers, solvents, and paints. Discards from hospitals may add pathogens and viruses to municipal refuse. Some industrial waste containing such pollutants as mercury, lead, polychlorinated biphenyls and asbestos also find their way into municipal waste.

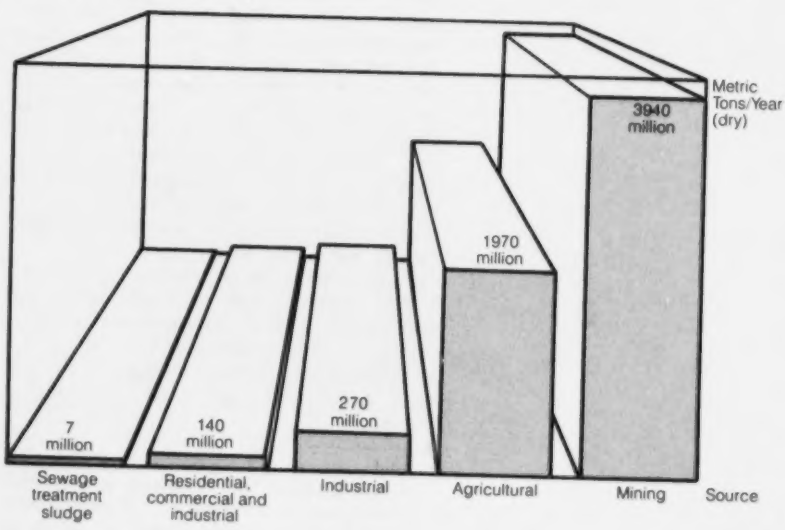
As municipal waste increases and land use becomes more important, new techniques will be needed to contain hazardous wastes. Further, it will become increasingly important to reclaim metals and the heat value in the waste which, in turn, will reduce contamination at land disposal sites.

Mining and metallurgical solid wastes

To date, more than 1.6 million hectares (4 million acres) of land have been disturbed by mining. Only 40 percent of this land has been reclaimed (Ref. 4). In addition to destruction of land forms, farm and range land, and wildlife habitats, mining activities can also lead to the degradation of stream and groundwater quality. Thousands of kilometers of streams, especially in Appalachia, are already polluted by acids and heavy metals discharged from waste piles and tailings. In many cases, runoff and leachates from mine waste contain dissolved solids that degrade water used for irrigation, especially in the West. Groundwater has also been polluted by leachates from mining wastes. Phosphate and other mining and processing plants sometimes discharge nutrients resulting in disruptive "blooms" of aquatic vegetation. Finally, some reagents such as cyanide, mercury, and arsenic used in the beneficiation of ores have both ecological and health impacts.

Increased extraction of uranium to meet energy needs will expand the number and size of tailings areas. Radioactive pollutants from uranium mining and milling, and to a lesser extent from phosphate and lignite mines, pose definite health hazards (Ref. 5, 6) unless carefully managed. Energy-related solid waste research requirements are discussed in the *Energy and the Environment* chapter.

Solid Waste (1976)



Source: U.S. Environmental Protection Agency, 1977.

Many of the research efforts required to identify and solve the problems of nonfuel mineral extraction are similar to those associated with energy resource extraction. However, the presence of much larger quantities of toxic materials in nonfuel mineral mining can lead to severe local problems which require special attention. These are now being addressed in a preliminary way by the efforts led by the Department of Interior to develop a Federal nonfuel minerals policy. Increased research will likely by required to answer the questions raised by the ongoing studies.

Agricultural and silvicultural wastes

Although agricultural and silvicultural residuals are widely dispersed throughout the nation, they can have serious local environmental implications. Unless farming and forestry practices markedly change, these residuals will increase significantly following growth in the agricultural and silvicultural sectors. For example, agricultural outputs above the current levels are projected to grow 15 percent by 1985 and 50 percent by 2010.

Local impacts may, in fact, be exacerbated by certain shifts which are now taking place, e.g., shifts to larger animal feedlots and offsite disposal of manure and other wastes.

Currently, 200 million hectares (494 million acres) in the United States are in forests managed primarily for the production of timber. About 23 million metric tons of debris from timber harvesting are left each year. Although some of the debris should be returned to the soil, much of the remainder must be disposed of or utilized. With an increase in demand for roundwood and sawtimber products, there will be a measurable decrease in forest land by 1990. The shortfall will likely be offset through intensive forest management of available land. Increased production from this land will generate more residues with the attendant problems of disposal or utilization.

Conversion of residues from agriculture and silviculture to animal feed or to products for uses such as composting for soil enrichment have been partially successful but need further study. Other resource recovery approaches include production of oil and gas from such residues.

Even though techniques are often available for solving many of the problems involving farming and forestry wastes, the real challenge is to link the technological solution with the problem. Dispersed pollution sources require innovative combinations of engineering, economics, and institutional factors.

Projected U.S. Discharge of Solid Waste (Percentages of 1975 levels)

Source	Noncombustible Wastes		Mining Wastes		Industrial Sludges		Municipal Sludges	
	1985	1990	1985	1990	1985	1990	1985	1990
Iron and Steel	180%	190%			150%	160%		
Nonferrous Metals	220%	270%						
Pulp and Paper	150%	150%			160%	170%		
Chemicals	130%	150%			150%	160%		
Electric Utilities	160%	140%			390%	440%		
Petroleum and Natural Gas	140%	140%			170%	180%		
Food Processing					150%	160%		
Coal Mining			190%	210%				
All Other Sources (including Oil Shale)	200%	260%	660%	1490%	500%	820%		
Total Output	170%	180%	310%	550%	250%	300%	180%	200%

Blank space indicates data not available. Values relative to 1975 levels.
Source: U.S. Environmental Protection Agency, 1978.

If we win here, we win everywhere. The world is a fine place and worth the fighting for...

Ernest Hemingway
1899-1961
For Whom the Bell Tolls, 1940

Global pollution

Goals

The goals of the global pollution research efforts are to understand the dynamic global processes within the biosphere and to develop the capability to predict the movement and changes of pollutants in the biosphere and the impacts of these pollutants on human health, ecosystems, and the climate. With adequate predictive capability, control of pollutants which pose threats to a healthful earth can be undertaken.

Until recently, pollution control has focused on urban and regional problems. However, concern is now being expressed about the global environment. The importance of protecting global resources is evident—we can neither easily repair, nor move away from, an unhealthful earth.

The most widely recognized worldwide environmental problems are marine pollution, carbon dioxide increases and ozone depletion. Our research role is to work closely with the relevant Federal agencies to provide an understanding of these global environmental problems in the oceans, the troposphere, and the stratosphere.

Marine pollution

Oceans cover more than 70 percent of the earth's surface. About one-third of the earth's atmospheric oxygen is produced by marine phytoplankton. Catches of ocean fish provide at least 10 percent of the world's supply of animal protein. Most marine fish depend upon coastal waters for food and spawning grounds.

However, the oceans of the world have become the depository for wastes carried by our rivers or dumped from barges, ships, and pipelines. Unlike rivers and lakes, the oceans have no outlet for this refuse. Oceans cannot be "flushed" clean.

At present, the oceans' ability to absorb these wastes is unknown. What is known, however, is that human wastes are present even on the high seas as evidenced by oil slicks and floating debris. Further, where marine areas have long been used as dumping grounds for wastes, such areas no longer support higher life forms.

Another problem to be addressed is whether chemicals used to disinfect effluents bioaccumulate through food chains. We must understand and predict the effect of waste discharges on the plants and animals of estuarine and coastal waters. Contaminants may enter the marine food chain by being metabolized, then transferred to higher life forms, and may accumulate to high concentrations. Thus, we need to understand the transport and fate of these contaminants and to model marine processes.

Accelerated energy and mineral resources development threatens the marine environment. Offshore oil operations, offshore nuclear power and industrial parks, liquefied natural gas terminals, ocean thermal energy conversion, and dredged material disposal all impact the marine environment.

With production of domestic oil and gas at full capacity in 1985, about 20 percent of our oil and 30 percent of our gas is expected to come from offshore supplies located near high-demand areas, particularly the East Coast and California. At present, only two percent of the oil spilled in the ocean is from offshore production. Increased exploitation of offshore deposits and the exploitation of deeper waters may increase that portion. In addition, there are more than 100 subsea mines which extend from land to recover coal, iron, nickel and copper ores, and limestone from beneath the ocean. (Undersea coal deposits account for about 30 percent of Japan's total production and more than ten percent of Great Britain's.) By 1980, subsea mining might be conducted economically as far as 50 kilometers offshore (Ref. 1). The dredging of the sea floor for minerals, sand and oyster shells is another area of great potential impact on the ocean environment. All of this exploitation of undersea reserves will disrupt ocean and estuarine ecosystems in as yet undetermined ways.

Direct marine experimentation, such as studying the movement of toxic substances in the ocean, is impossible due to both high costs and ethical considerations. Thus, other approaches such as microcosm studies are necessary. However, most of these studies have failed to adequately simulate ecosystems. For example, in the open ocean many large-scale elemental exchanges and reac-

Sources of Oil in the Oceans

Source	Percent of Total Volume
Marine transportation	34
River runoff	26
Atmospheric rainout	10
Natural seeps	10
Municipalities	10
Industrial wastes	8
Offshore production	2

Source: Harrald, J. R., et al., 1977

tions occur at the air-water interface—processes not simulated in current microcosms. Laboratory simulation should be confirmed, where possible, through comparison with actual environmental situations.

Research to determine the fate and effects of waste materials dumped into the oceans must include tracking the movement of the waste from the dumpsite and studying the types of biological communities in the areas traversed by the wastes. An understanding of how those wastes are assimilated will allow us to predict the levels to which various marine communities will be exposed. We can then determine which marine pollutants are most harmful under different situations. Finally, effective management and control can be developed.

Special attention should be given to the potential hazards to humans through transport of pollutants in ocean waters. We need to quantify the effect of perturbations to marine ecosystems to help avoid contamination of human food supplies. One way to do this is to use specific marine organisms as indicators of harmful levels of marine pollution.

Further research is necessary into receational water quality, shellfish contamination and measurement techniques for disease-causing microorganisms. State and local authorities can use this information to minimize health risks in recreational and food-producing waters. Research should be undertaken to understand the "carrying capacity" of marine ecosystems.

Contaminated sediment waste outfalls, waste dump sites, ship accidents, and industrial operations can seriously pollute marine waters. On the other hand, the ocean can be an excellent site for residue disposal since it constantly recycles carbon, nutrients, and other chemicals. Special attention should be directed toward determining the productivity of estuarine systems as a function of contamination. A model estuarine system could be used to simulate the dynamics of productivity, with an emphasis on interaction of growth stimulators (light, nutrients) and inhibitors (toxicants).

Tropospheric pollution

Like the oceans, the Earth's atmosphere is being altered by human activities. One of the most significant of these alterations is the addition of enormous volumes of carbon dioxide from the burning of fossil fuels in industrial, electrical, and automotive power plants.

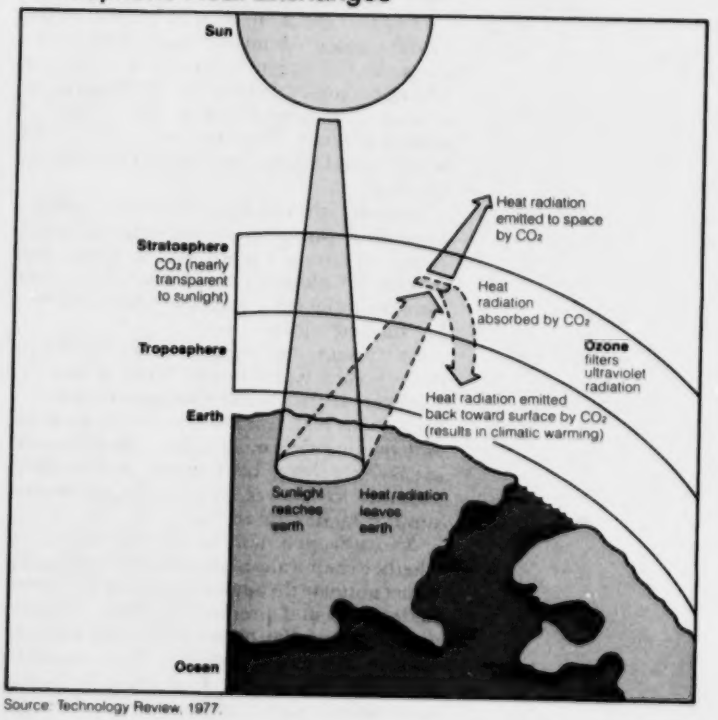
Along with the Department of Energy and the National Oceanic and Atmospheric Administration, EPA participates in a major research program to determine the potential hazards of the large-scale release of carbon dioxide.

Additional information on carbon dioxide in the atmosphere is required in three areas—the carbon cycle, climatic effects, and socio-economic and ecological effects. We cannot yet accurately predict the rate of carbon dioxide exchange among the air, the oceans, and the land. Thus, we must improve the monitoring and modeling of the processes that control these exchange rates.

The ocean is also a key part of the carbon cycle. In the ocean, the most important process is the circulation and mixing of surface water with deep water. Once dissolved, carbon dioxide is mixed into deep water. Carbonates in the ocean floor dissolve and combine with carbon dioxide to create bicarbonate buffers. On land, the processes that most strongly influence the net flux of carbon dioxide to or from the atmosphere are photosynthesis, respiration, and combustion and decay of biomass, including coal.

A first step in climatic effects research is improvement of our global air circulation models in order to understand and predict

Atmospheric Heat Exchanges



Source: Technology Review, 1977.

climatic fluctuations and trends. Extensive monitoring of carbon dioxide concentrations, temperature, precipitation, winds and clouds, is being conducted.

These efforts should enable us to predict the consequences of a changing climate in terms of possible crop and ecosystem shifts and their impact on human welfare. Increases in carbon dioxide concentrations may lead to global temperature rises, longer growing seasons, and increased yields—the "greenhouse effect" (Ref. 2). Precipitation changes could have an even greater impact than temperature changes, turning croplands into deserts and vice versa.

Greater fossil fuel combustion, including expanded coal use, will lead to further increases of atmospheric carbon dioxide. Between 1958 and 1976, carbon dioxide in the atmosphere increased by about five percent. If atmospheric carbon dioxide were to double, the global temperature could increase by as much as 2°C. At the anticipated growth in fossil fuel combustion, this increase could occur by the year 2025 (Ref. 2). By way of contrast, the maximum normal shifts in global temperature over the past centuries have been less than 1°C. The ensuing environmental problems associated with a carbon dioxide increase could include the melting of the polar ice caps. This could lead to significant changes in ocean levels and circulation patterns. Dramatic changes could occur in cloud cover and rainfall patterns.

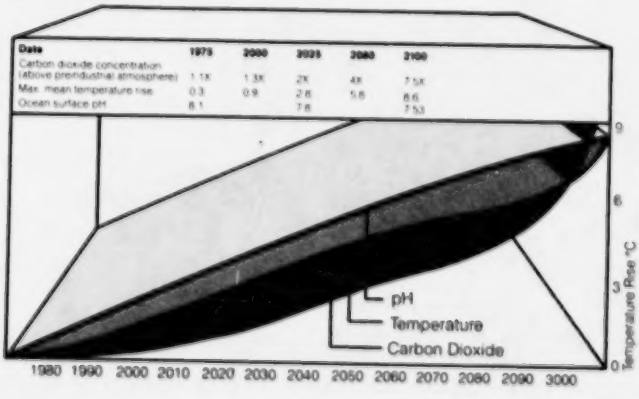
We should expand our studies on atmospheric turbidity, solar radiation changes, urban climate, acid rain, and visibility. In addition, we should initiate research to include global cycles for such substances as nitrogen, phosphorus, and sulfur (see the *Nonpoint Sources and Watersheds* chapter).

Stratospheric pollution

Another phenomenon of global importance is the potential depletion of the ozone layer due to the spread of human-produced ozone-destroying substances into the stratosphere. The ozone layer shields the earth's surface from exposure to high concentrations of ultraviolet radiation. Any depletion of this shield would result in serious harmful effects to people and other living things. The major ozone-depleting substances identified so far are halocarbons (notably freon), nitric oxide from the exhausts of high altitude aircraft, and nitrous oxide from chemical fertilizers and other forms of nitrogen in soils.

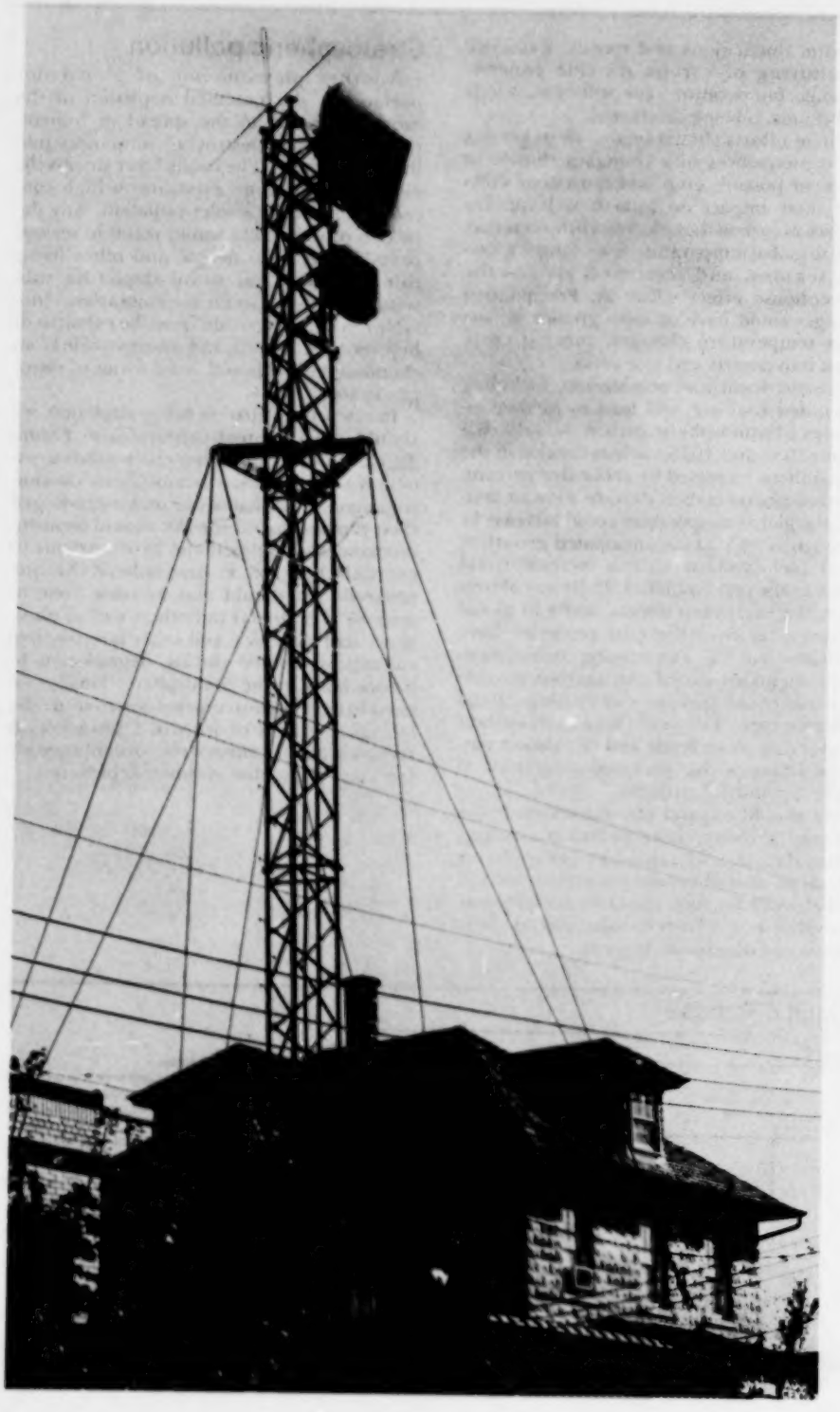
In research efforts on ozone depletion, we should monitor methylchloroform, Freon-22, chloroform, and other compounds to establish trends in their stratospheric concentrations and to enhance our understanding of their removal processes. We should measure methane and nonmethane hydrocarbons to establish their role in stratospheric chlorine removal. We should also measure concentrations of hydroxyl radicals as well as phosgene, acid chlorides, and other intermediate substances formed during degradation of halocarbons in the atmosphere. Finally, we need to develop instrumentation to study the biological effects of increased ultraviolet-B radiation and to estimate the "greenhouse effect" on climate due to ozone depletion.

Climatic Trends



Note:
This is one of several projections of future trends in global concentrations of carbon dioxide and related climatic changes. For further information, see Ref. 3, 4, 5, and 6.

Source: Chemical & Engineering News, 1977.



We look at it and do
not see it;
Its name is the
Invisible.
We listen to it and do
not hear it;
Its name is the
Inaudible.
We touch it and do
not find it;
Its name is the
Subtle.

Lao Tzu
550 B.C. (?)
The Way of Lao Tzu

Nonionizing radiation

Goals

The goals of the nonionizing radiation research effort are to understand the nature and severity of the health effects caused by the pervasive sources of nonionizing radiation and to help to determine what exposure standard would protect public health.

We are exposed to nonionizing radiation* from many sources—electric power lines, radio and television transmissions, diathermy equipment, and radar and microwave transmission facilities. Over one million workers in medical, telecommunication, and construction occupations are regularly exposed to nonionizing radiation.

The number of consumer products that emit low-level, nonionizing radiation is growing rapidly. Some 100 million television sets are used in the United States with 13 million manufactured annually. Over 1.5 million microwave ovens are now used as compared with only 40,000 ovens ten years ago. As many as 11 million are expected to be produced by the end of 1980. The number of mobile radios doubled last year and is expected to continue to increase (Ref. 1).

Exposure to nonionizing radiation from FM radio and UHF television is now of special concern because of the large number of people exposed, the length of the exposure, and, in some instances, the intensity of the exposure. Potential future applications of nonionizing radiation in the radio frequency and microwave bands may create even greater problems. For example, the Federal Communications Commission reserved an increased portion of the radio frequency spectrum for use in personal, portable communication systems (Ref. 3). One futuristic proposal—a Solar Power Satellite System—would collect solar energy in outer space and transmit it to earth in the form of microwaves (Ref. 4).

Despite the rapid growth of nonionizing radiation sources, there is little agreement on the nature and extent of the health hazards resulting from exposure to such radiation. For example, the Soviet Union and the Eastern European countries have taken a much more conservative approach in controlling such radiation than has the United States. This has resulted in a marked difference in maximum occupational exposure standards used in various nations (Ref. 3).

Exposure standards in the United States are based only on consideration of the effects due to heating within body tissue (thermal effects) (Ref. 5). Other nations consider other (nonthermal) effects in setting their exposure standards. However, such effects have not yet been sufficiently demonstrated within the United States to cause us to change our standards.

Nonthermal effects of nonionizing radiation are much less well understood than thermal effects. For example, the FM radio spectrum includes a resonant frequency at which the radiant energy is preferentially absorbed in the human body (Ref. 6). Recent EPA research indicates that chronic, low level exposures of animals can produce observed biological effects (for example, impaired function of immune defense mechanisms and abnormal behavior responses) (Ref. 7, 8, 9) in the absence of detectable heat generation. Such data and the conservative approach employed in Eastern Europe demand that we rapidly improve our understanding of the subtle effects of nonionizing radiation. Improved health effects data could then serve as a basis for tightening the nonionizing radiation exposure standard.

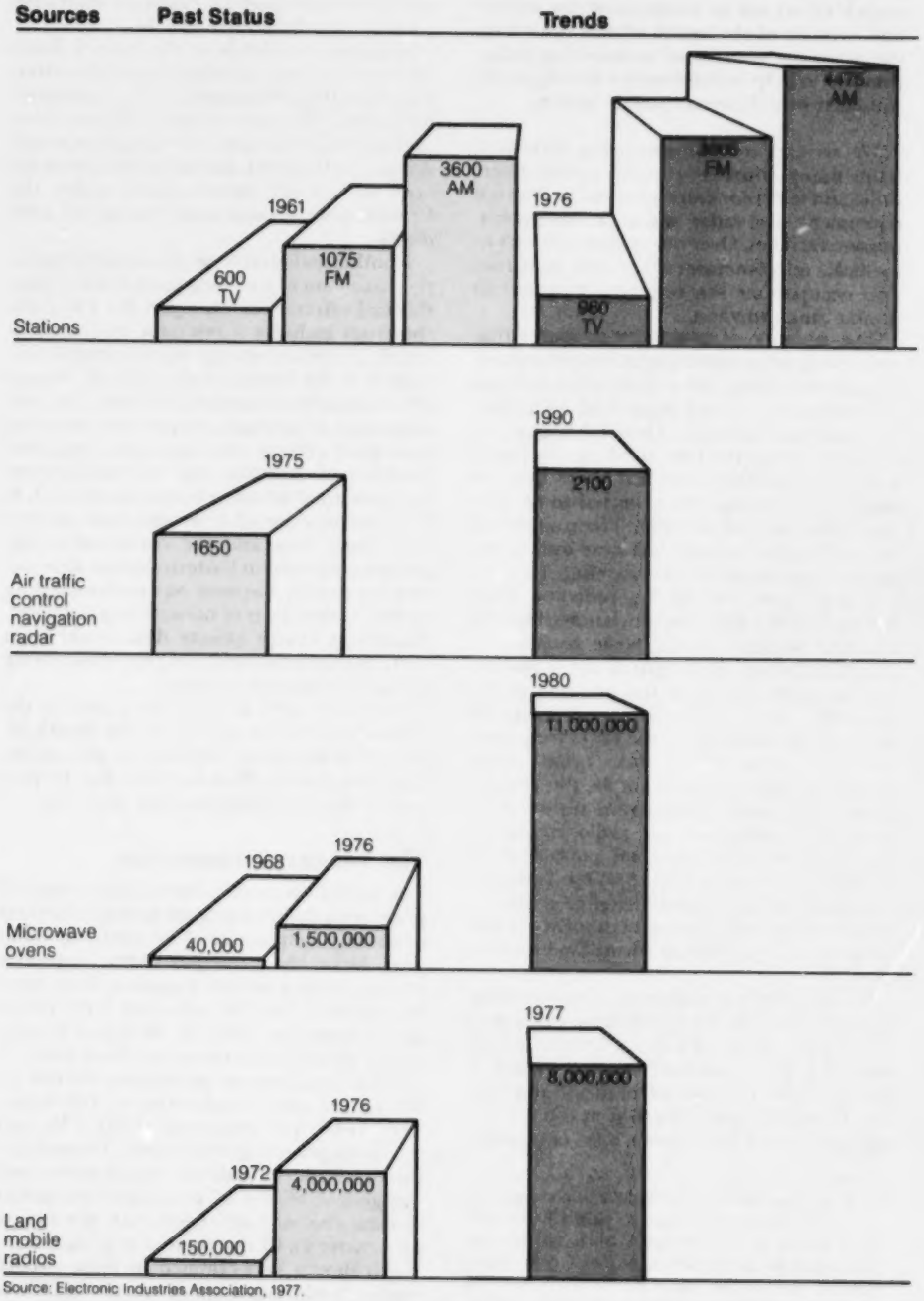
Currently EPA is conducting one of the largest research programs on the health effects of nonionizing radiation in the nation. This integrated effort accounts for 15 percent of the total Federal effort (Ref. 10).

The research response

A critical element in the nation's research program is determining the biological effects of specific frequencies of nonionizing radiation. Since the principal radio frequency sources of population exposure have been identified as the FM radio and UHF television frequencies (Ref. 3), biological experiments should concentrate on those sources. Animal exposure experiments should be conducted using frequencies of 100 megahertz (FM), 425 megahertz (UHF-TV), and 2,450 megahertz (microwaves). Teratologic, immunologic, behavioral, reproductive, and cytogenetic effects of prolonged low-power densities below 1,000 microwatts per square centimeter (1/10 the current exposure standard) should be examined in these experiments. A microwave spectrometer capable of sweeping a broad frequency range should be developed to define limited frequency ranges of particularly high absorbance in biological

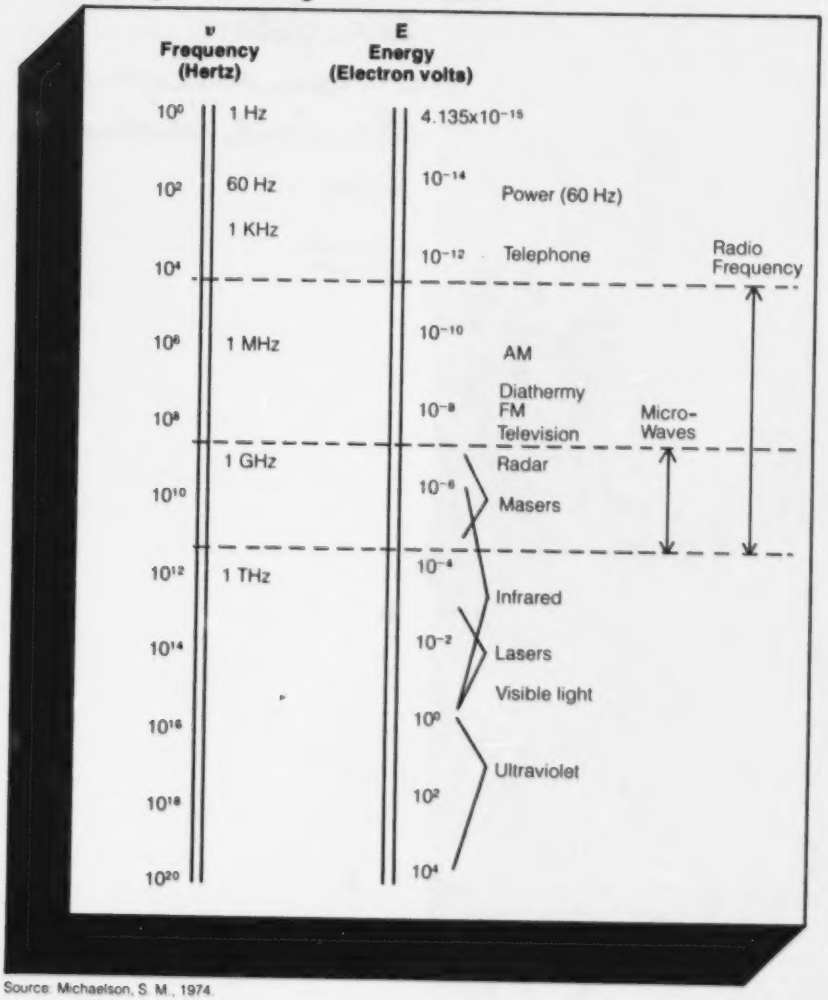
* Nonionizing radiation includes radio waves, microwaves, infrared radiation, visible light, and part of the ultraviolet band. Such radiation is physically incapable of ionizing molecules (ionization results in an electrically charged molecule). This is in contrast to higher frequency radiation, such as X-rays or gamma rays, which are sufficiently energetic (10^2 to 10^{11} electron volts) to produce ionization (Ref. 2).

Sources of Nonionizing Radiation



Source: Electronic Industries Association, 1977.

Nonionizing Electromagnetic Radiation



Source: Michaelson, S. M., 1974.

samples. Epidemiologic studies in urban areas exposed to these radio frequencies should be conducted to support the laboratory work.

The United States standard for occupational exposure for nonionizing radiation is based upon theoretical calculations of the heating effects that humans can tolerate without adverse effects. A systematic, experimental evaluation of this approach is required in the nation's research efforts to determine whether a standard based solely on thermal effects provides adequate protection of public health. As part of this evaluation, we must improve our knowledge of the mechanisms involved in the nonthermal effects of such radiation. We must determine if certain human systems (such as reproductive, immunologic, neurologic, hematologic, and cytogenetic) are more sensitive to radiation levels below the occupational standard of 10,000 microwatts per square centimeter. We must also determine if there are effects from long-term, low-level exposure to nonionizing radiation. Latent effects such as cancer or early mortality are of prime interest. Especially in these efforts, we will have to rely extensively on epidemiologic studies with populations exposed to nonionizing radiation within their workplace.

The land belongs to the future... we come and go, but the land is always here.

Willa Cather
1876-1947

Nonpoint sources and watersheds

Goals

The goals of the research efforts on nonpoint sources and watersheds are to understand how all nonpoint sources of pollution contribute to environmental degradation, especially in watersheds, and to determine how effective various monitoring and control techniques are in identifying and abating, respectively, the deleterious effects of nonpoint source pollution.

Half or more of all water quality problems are caused by nonpoint source pollution.* Urban stormwater runoff; agricultural, forestry, mining, and construction activities; waste disposal; watershed disruptions; and acid precipitation are the major nonpoint sources of water pollution.

Nonpoint sources of pollution result from the complex interactions of our use of the land with natural processes such as rainfall or snowmelt runoff. The nature of the pollution varies widely with human activities, natural weather phenomena, and local soil and topological conditions. Within a given year, for example, the major portion of nonpoint source pollution may occur during a brief rainstorm or series of storms.

Nonpoint source runoff

Water pollution abatement in the United States has been more successful in dealing with point sources than with nonpoint sources. Thus, as greater control is applied to point sources, nonpoint sources of water pollution will predominate. Because of its dispersed and often random nature, however, nonpoint water pollution will not be easy to control even with much greater efforts.

In addition to the quantity of pollutants produced by the different sources, of major importance is a pollutant's relative impact on water quality and uses. Water quality is also affected by the timing and distribution of the discharge as well as the dilution and assimilation capacity of the receiving water. Because of the interlinking of these factors, nonpoint sources are responsible for the major water quality problems in many areas of the country. For example, results of EPA's National Eutrophication Survey, as well as other Federal and state monitoring activities, indicate nutrient concentrations to be highest in streams which drain farmland (Ref. 1). Without control of such pollutants, adequate abatement of eutrophication in surface waters is unlikely to occur. It is well to remember that many of these pollutants—especially sediments and nutrients—are, in fact, valuable resources which become pollutants only because the land was used unwisely.

Runoff from agricultural and forestry activities may become an even greater problem if, as expected, production of agricultural and forestry products increases during the next two decades. In this context, EPA must work closely with the Soil Conservation Service to develop and disseminate the information necessary to correct this problem. In addition, runoff from coal mining also contributes significant loads of pollutants, a problem which is addressed in the *Energy and the Environment* and *Solid Waste* chapters of this report.

Although we have made some important progress in understanding and controlling nonpoint water pollution in the last seven years, there remains considerable uncertainty about the effectiveness of current and proposed methods of nonpoint pollution control. Thus, regulatory efforts and research must go hand-in-hand to address the variety of complicated problems listed below:

Land Use. Urbanization takes thousands of hectares of farmland out of production each year. To compensate, marginal lands are farmed, requiring greater application of fertilizer and pesticides which, in turn, may lead to increased runoff of nutrients and toxic materials, as well as increased erosion.

Crop Production and Pollution Control. If farmers had methods to determine optimum rates and timing for applying nutrients and pesticides, they could conserve energy and minimize pollution. These methods could encompass such schemes as soil testing or information services to inform farmers of variables such as rain probability, wind conditions, and pest infestation levels.

Recycling. With increasing costs, especially for energy, more efficient farming methods could involve recovering and recycling resources which are currently lost in the form of water pollution. For example, nutrient runoff could be captured and used to produce vegetation to be converted (by on-farm methods) to energy. The conversion

* Nonpoint sources are those whose water effluents are not narrowly channelled or contained by pipes or holding ponds. In this chapter, nonpoint sources also include acid precipitation and other pollution transported through the atmosphere. The pollutants of greatest concern from these sources are sediment, dissolved inorganic compounds such as strong acids, nutrients, pesticides, toxic metals, organic compounds, and pathogens.

methods used may also handle animal wastes and crop residues. (See the *Solid Waste* chapter.)

Pest Management. Pesticides are among the most pervasive and difficult to control of the nonpoint source pollutants. Research can help to reduce the use of pesticides through two major efforts. As mentioned above, farmers could be provided with localized advice on precisely when to apply pesticides for maximum effect. An even better approach may be the use of alternatives to pesticides, such as biological agents and predatory species. In this latter area, both EPA and the Department of Agriculture are conducting research.

In order to advance the state of knowledge of nonpoint source control in these four areas, it will be necessary to move the research beyond the current laboratory and small-scale projects to major hydrological areas such as watersheds. Although obviously more difficult, watershed studies will be required to understand the interactions of many pollutants from many sources, and the effectiveness of various controls now being used to reduce the pollutant loadings in the streams. These studies should concentrate on major nonirrigated crop production regions. They should be aimed at giving us, at the watershed level, improved predictive models for the effects of nonpoint source perturbations and improved best management practices for agricultural and forestry activities.

The capabilities of other Federal and state agencies in dealing with nonpoint source pollution will be a key factor in the successful application of the research results in the field.

Urban stormwater

In urban areas, the principal nonpoint source concern is stormwater management. A nationwide survey of public works officials conducted in 1976 identified urban flooding and its associated pollution caused by inadequate storm sewers as the **number one urban problem.** As suburban land continues to be developed, the problem will increase. In response, a few urban areas have initiated programs to improve stormwater management.

Nonpoint Sources of Water Pollution[a] (Millions of tons per year)

Nonpoint source category	Sediment	BOD	Nitrogen	Phosphorus	Acids[b]	Salinity[c]
Cropland	1870	9	4.3	1.56		57.3
Pasture & range	1220	5	2.5	1.08		
Forest	256	.8	.39	.089		
Construction	197					
Mining	59				3.1	
Urban runoff	20	.5	.15	.019		
Rural roadways[d]	2	.004	.0005	.001		
Small feedlots	2	.05	.17	.032		
Land fills		.3	.026			
Subtotal	**3626**	**15.8**	**7.4**	**2.8**	**3.1**	**58.1**
Natural background	1260	5.0	2.5	1.1		
Total	**4886**	**20.8**	**10.0**	**3.8**	**3.1**	**58.1**
Municipal point sources after treatment, 1975	2.1[e]	1.9	1.5[f]			
Industrial point sources after treatment, 1975	7.9[e]	2.2	.11[f]		.26	12.5

[a]83.6 million hectares (207 million acres) in public lands (14% of contiguous U.S.), mostly in Rocky Mountain region, were excluded due to inadequacy of information.

[b]As $CaCo_3$.

[c]From irrigation return flow.

[d]Deposition from traffic related sources.

[e]Suspended solids.

[f]Nitrogen plus phosphorus.

Sources: Midwest Research Institute, 1975.

Although stormwater runoff typically occurs only during brief periods, the quantities of sediment, nutrients, chemicals, and toxic materials dumped into streams during the storm periods dwarf the quantities of such materials released by the municipal treatment plants throughout the entire year. This problem has serious implications for municipalities using the streams for water supply as well as for other downstream users.

To understand more fully the significance of such pollution, we should conduct studies to determine both the immediate and long-term effects of stormwater discharges in streams and lakes used for drinking water. We should evaluate which runoff control techniques are most protective of the public health with emphasis on improved practices for urban land use and runoff attenuation, drainage design criteria, and upstream storage leading to controlled release. We should also encourage more cities to adopt stormwater management systems by determining equitable means of apportioning the costs of urban runoff control.

Groundwater contamination

Groundwater quality may also be threatened by nonpoint source pollution. It is conceivable that most of the aquifers in the United States may be contaminated by the year 2000 unless currently uncontaminated waters are protected. Without such protection, the United States soon may not be able to use much of its groundwater due to nonpoint source pollution. It takes decades or centuries for the geochemical processes to reclaim the groundwater once contaminated. The only viable approach is to prevent the contamination in the first place.

Urban Stormwater

Residuals	Urban runoff and treated municipal wastewater (kg/ha/yr)	Percent attributed to urban runoff
Suspended solids	7,426	99
Ultimate biochemical oxygen demand	514	80
Chemical oxygen demand	1,023	84

Data are national averages.
1 kilogram (kg) = 2.2 pounds; 1 hectare (ha) = 2.5 acres
Source: Colston, N. V., 1974.

In addition to the contamination of some groundwater sources, others are lost through climatic fluctuations. Many regions dependent on groundwater have suffered recent droughts. Due to our rate of use of groundwater supplies, it may be worthwhile to consider new techniques to recharge depleted aquifers, including the use of municipal and industrial wastewater, and to reclaim polluted aquifers.

In past years, several projects using technology developed for desalination have been conducted to recharge and reclaim groundwaters. For example, reverse osmosis has been used to treat acid mine drainage and chemical and saline wastes prior to their release into groundwater recharge areas. Earlier studies projected costs of 26 to 31 cents per thousand liters of water, a cost that was not competitive with local water rates of 16 to 20 cents per thousand liters (Ref. 2). Since that time, however, conditions have dramatically changed in many areas, and the costs of treating groundwater may have become more competitive. Some of the shelved technologies should, therefore, be reexamined to determine their current cost-effectiveness.

Besides providing improved techniques for safe recharge, we should launch a nationwide effort to determine the extent of contamination of groundwater supplies by toxic chemical and biological substances. This monitoring effort must be supported by improved methods for sampling subsurface waters and for modeling the transport of substances in those waters.

Because so many people in the United States depend on groundwater as their only supply of drinking water, it is essential for maintenance of public health and environmental productivity that we direct increasing attention to the preservation of clean groundwater supplies.

Air pollution impacts

Another major, if somewhat unexpected, nonpoint source of water pollution is polluted air. Substances enter the air from many sources, mix with other pollutants and change character, are transported up to hundreds of kilometers and return to the earth either as dry particles or in precipitation. Thus, sulfur oxides, nitrogen oxides, heavy metals, and other pollutants from power plants, industry, and automobiles affect the quality of the land and water at great distances from the sources.

Airborne nutrients, when deposited in water, can aggravate eutrophication, e.g.,

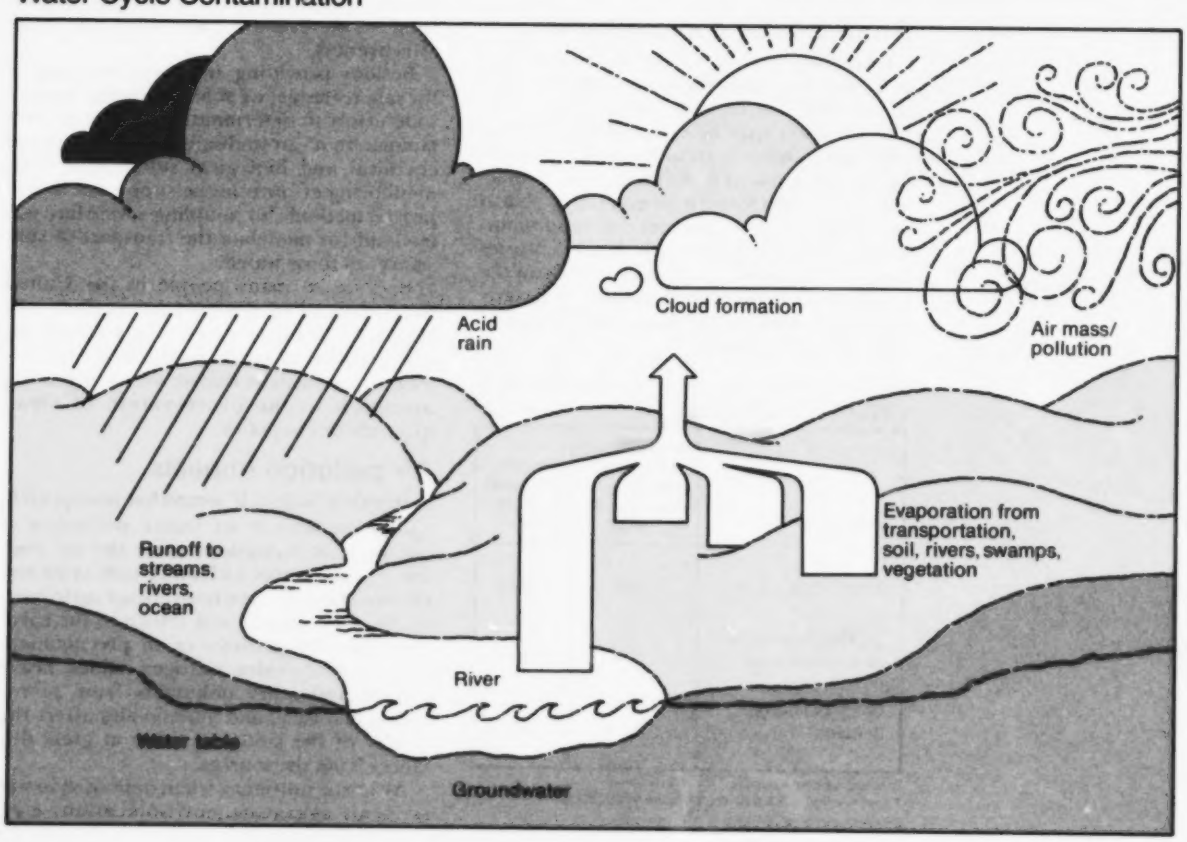
growth of unwanted algae. Dust contributes to waterborne sediment in streams and lakes. Vegetation may be directly harmed by both gaseous and particulate air pollutants. Acid-causing pollutants (primarily from fossil fuel combustion) have increased the acidity of precipitation. The formation of acid rain is discussed further in the *Air Pollution* chapter.

Nonpoint runoff from acid rain has been increasing significantly for a number of years. The problem was first widely recognized in Scandinavia where scientists at the 1970 Stockholm Conference on the Environment reported steady increases of sulfur and nitrogen compounds and acidity in rainfall and snowfall in Sweden (Ref. 3). Acid precipitation poses a special threat to such cash crops as forests and fish. At the International Conference on the Effects of Acid Precipitation, held in Norway in 1976, damages to forest, crops, fish, and materials such as steel and paint were documented. Also of particular concern is the potential long term damage to soil fertility. Once leached of their vital nutrients and minerals, such soils may require several centuries to be restored.

In the United States, recognition of the damages of acid precipitation has been slower than in Europe. Even in the northeastern United States where acid precipitation is known to be present, data are scanty and have been gathered only within the last two decades. Although rates of forest growth have declined in the Northeast, this decline cannot as yet be definitively related to acid precipitation. It is known, however, that acid precipitation damages foliage, affects germination of conifer seeds and the growth of seedlings, reduces the availability of soil nitrogen, decreases soil respiration, and increases leaching of nutrients. Although subtle, these effects will likely become more significant with time and may cause irreversible changes in important ecosystems.

Research indicates that strong acids, such as sulfuric and nitric acids, are responsible for

Water Cycle Contamination



most of the acidity in the precipitation. The normal pH value, a measure of acidity, for rain is about 5.7, indicating slight acidity. A pH of 7.0 is considered neutral, with pH values lower than that considered acidic. Very acidic rainfalls having a pH of 4 or lower have been repeatedly observed in the northeastern United States. The resulting acidification of lakes, particularly that occurring in areas of naturally acidic soils such as those derived from the carbonate-poor granite rocks of the Northeast, appears to be having major detrimental effects on the fish populations.

Of major significance for future regulatory efforts is the fact that the largest fraction of the pollution causing the acidity appears to be transported from sources as far away as the industrial Midwest and southeastern Canada. We need to know much more about the atmospheric chemical transformations as well as the meteorological factors involved in acid precipitation.

Estimates of the long-term threat of acid rain damage to soil fertility in terms of food and forest production and diversity are needed. With massive shifts to coal combustion likely, the need for these estimates is crucial. Nutrients may become unavailable to vegetation or may appear in toxic concentrations in the soil.

Surface water impoundments in the Northeast may become more acidic, leading to increased leaching of toxic metals such as lead and copper from municipal water supply pipes. Since it is evident that air pollution, in addition to being a direct human health threat in itself, contributes to the degradation of water, soil, and vegetation, it is essential to expand research on this largely neglected nonpoint source of pollution in watersheds.

Integrated watershed management

A unified approach to manage an entire watershed ecosystem requires a fundamental understanding of the dynamics of the physical, chemical, and biological interactions that occur within its boundary. With such an understanding, it will be possible to proceed toward development of a predictive capacity that will allow us to anticipate the extent of ecosystem modification resulting from a particular perturbation, be it from a point or nonpoint pollutant source.

Several Federal programs address environmental perturbations in watersheds, but a coordinated Federal approach to watershed management is needed. The lack of an adequate in-depth research base has resulted in a lack of understanding of watershed response to human-induced environmental impacts.

Research on watershed ecosystems must be expanded in order to develop an improved capability to predict the consequences of environmental perturbation. As our knowledge of environmental problems has grown, we have come to realize that we need to know how impacts of such stresses as nutrient and pesticide loadings, oil and toxic material discharges and spills, and complex industrial waste discharges affect the populations of living organisms as well as the physical and chemical factors within the ecosystem. If we can relate such material and energy inputs through the ecological processes to the quality of the water and other materials leaving the ecosystem, we will have a stronger basis for enlightened regulatory actions.

In completing one discovery, we never fail to get an imperfect knowledge of others of which we could have no idea before, so that we cannot solve one doubt without creating several new ones.

Joseph Priestly
1733-1804
Experiments and Observations on Different Kinds of Air, 1786

Measurement and monitoring

Goals

The goals of the measurement and monitoring research effort are to anticipate potential environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends.

Environmental monitoring is the systematic measurement of the physical, chemical, and biological properties of the environment. It is, essentially, a two phase effort of data collection and data analysis. The **data collection** effort involves the monitoring of exposures of living organisms, the effects of these exposures (Ref. 1-4), pollutant sources, and the ambient environment. **Data analysis** must then be performed to allow policy-makers to identify environmental problems, develop effective regulatory solutions, and assure that environmental improvement and health protection is accomplished. Thus, the collection of data—on source emissions, ambient concentrations, exposures, and effects—is accompanied by analyses of the relationships among these factors. By linking these data in compatible (often computerized) form, geographical variations in emissions, concentrations, and mortality/morbidity rates can be determined.

Data collection and analysis efforts must be supported by continued research on environmental measurement methods. Environmental measurement research includes not only developing instruments and methods for physical and chemical measurement, but also establishing concepts for determining biological and ecological impacts.

Data collection

Exposure monitoring measures the total exposure of biological organisms to pollutants via all important routes. Exposure monitoring identifies pathways by which individuals are exposed to pollutants, and measures the exposure. These measurements are then summed across all pathways to estimate the total dose. For some pollutants, the measurement of total body burden (e.g., lead in the blood) may be more cost-effective than monitoring all pathways since lead enters the body via many different routes including air, water, paint chips, road dust, and food. This approach is particularly valuable in determining the cumulative health risk of chronic exposure to low-level toxic substances in the environment and, subsequently, in identifying the most effective means of protecting public health.

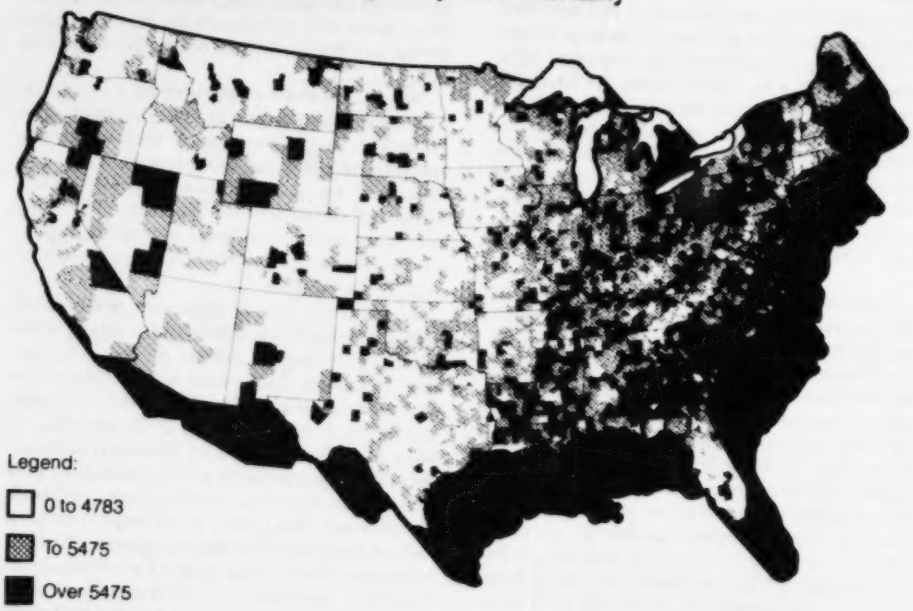
We can estimate exposures by a combination of measurements at stations, studies of transport processes, indoor measurements, models of personal activity patterns, and "contour" maps of pollutant concentrations. However, estimates should be validated by direct measurements of exposure using appropriate instrumentation such as personal air quality monitors.

Long-term monitoring of **biological trends** establishes baseline and trend data for assessing ecological effects of chronic, low-level pollution. These effects are often subtle and difficult to quantify. This is due to a poor understanding of the long-term, chronic effects of pollution, lack of dose-response information (particularly at the community and ecosystem levels), inadequate ambient monitoring data, and, most importantly, a lack of baseline information against which to measure effects. This type of monitoring is, however, essential to anticipate potential health risks from chronic low-level pollution from toxic substances, and to develop more effective regulatory approaches.

By collecting and storing environmental specimens such as tissues, in a National Environmental Specimen Bank, it may be possible to identify geographic and historical variations in pollutant burdens. It may also be possible to determine background levels of pollutants and distinguish them from human contributions. This would allow retrospective analyses as more sensitive techniques are developed or new pollutants are identified. Specimen banks have been criticized because of lack of standardization of methods for collecting and preserving specimens, but they have been highly useful for establishing tissue burdens in evaluating DDT, mercury, and lead. Research into the standardization of collection, preservation, and analysis is underway but no coordinated Federal effort exists.

EPA regulates many environmental contaminants either at the source or in the ambient environment. Regulation of sources may entail the registration of a product or the limitation of effluents released into the environment. Monitoring in support of such regulations often involves verification of both the data submitted in support of registration and data reported by self-audits at the sources (Ref. 5). The **source monitoring program** aims at characterizing more adequately the chemical composition of industrial wastes

Cardiovascular Diseases, Age-Adjusted Mortality

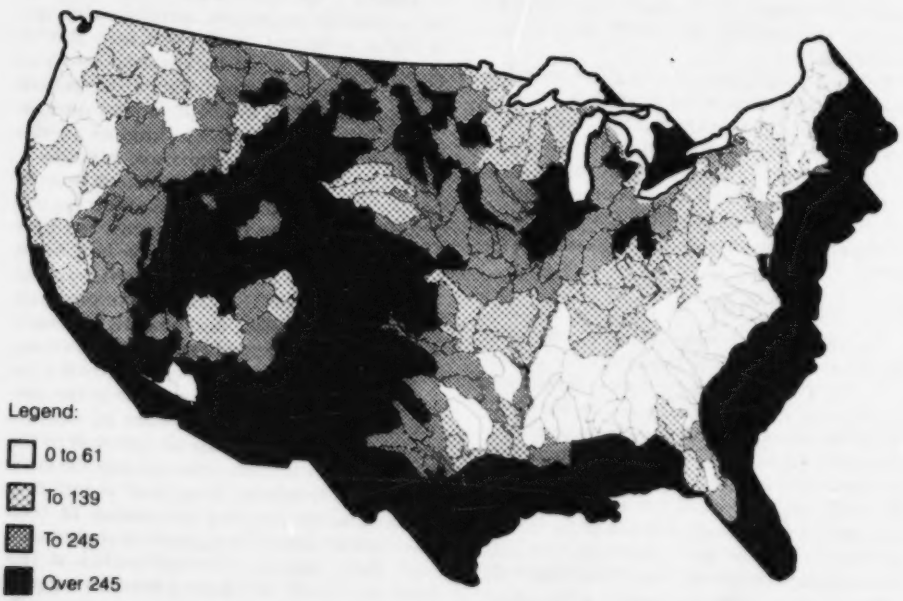


Legend:

- 0 to 4783
- To 5475
- Over 5475

Annual death rate per million population, blacks and whites combined (1968-72).
Source: Council on Environmental Quality, 1977, UPGRADE, Graphics and Analysis System (Unpublished).

Total Hardness of Surface Water



Legend:

- 0 to 61
- To 139
- To 245
- Over 245

Milligrams per liter as $CaCO_3$; annual mean values — 1976 water year.
Source: Council on Environmental Quality, 1977, UPGRADE, Graphics and Analysis System (Unpublished).

by improving emissions estimates, verifying industry self-monitoring reports, or creating monitoring networks. This information is important in assuring that regulatory strategies are being complied with.

The **ambient monitoring** program seeks to develop new networks to understand such problems as acid rain, visibility degradation in western states, fine particles in the atmosphere, and significant deterioration of air quality in pristine areas. Regulation to clean up the ambient environment and protect public health involves setting standards for safe levels of contaminants such as sulfur dioxide in the air, cadmium in sludge, or Kepone residue in fish. Regulatory devices such as state implementation plans for air pollution or area wide plans for water pollution control are used. Ambient monitoring of trends can provide a useful way to determine the effectiveness of environmental cleanup. This includes investigating trends on a regional or local basis as well as monitoring national trends.

Data analysis and display

With the increased incidence of chronic diseases, especially those diseases with long latency periods, determining the correlation between environmental and health data has become correspondingly more important. Such data correlations may be used to identify relationships among source emissions, ambient concentrations, exposures, and biological effects.

Several Federal agencies collect related data for different purposes. Hence, the data are often incomplete, incompatible, or of little use to decision-makers in other agencies. A serious attempt must be made to standardize the data collection, analysis, storage, and retrieval methods of agencies that collect environmental and health effects data.

The consolidation of high quality environmental and health data from different agencies into compatible automated systems for rapid retrieval and analysis should be one of our primary goals. For example, a graphics and analysis system called UPGRADE is now being evaluated by EPA. Developed under the auspices of the Council on Environmental Quality, this system allows comparison of environmental monitoring data collected by EPA and the U.S. Geological Survey with health and demographic data collected by the National Center for Health Statistics and the Bureau of the Census.

Using UPGRADE maps one can visually compare the relationship between deaths from cardiovascular disease and the hardness of water supplies, or the relationship between respiratory disease mortality and high concentrations of particulate matter. Such analyses will become increasingly useful for policy-makers as the data base upon which we can draw grows in scope, quality, and standardization.

Measurement methods and quality assurance

Appropriate measurement methods and quality assurance techniques must be developed to support the establishment of effective monitoring systems. In the future, physical, chemical, biological, and statistical methods to measure thousands of pollutants and effects in the air, water, biological tissues, and wastes will be needed. These methods must work under varying extreme measurement conditions such as hot turoulent gases in factory stacks, organics at the parts per trillion level in drinking water, and viruses in sewage sludge. Recent research has expanded our capability to measure traces of toxic substances in air and water and to analyze single samples for multiple contaminants. In addition, continuous on-site analyzers are being developed to measure pollutants too unstable to survive transport from the field to the laboratory, and techniques are being developed for sampling and preserving heterogeneous substances such as sediments, soil, airborne particles, and solid waste. A stringent program for quality assurance must be operational to assure that these measurements will be consistent and useful.

The research response

Our **exposure monitoring** program should emphasize three major study areas. First, we should develop and improve equipment that can be carried by individuals to directly monitor their exposure to air pollutants. The data from such monitors can then be used to determine the frequency distribution of exposure for entire community populations. Second, we should expand our ability to use microorganisms for rapid screening of compounds to determine exposure/response relationships for critical receptors. Third, we must improve our ability to estimate the total exposure of populations at risk from all routes of exposure to ubiquitous pollutants such as toxic substances. This can be accomplished by using body burden measurements augmented by ambient measurements and models.

Our **biological monitoring** program should emphasize improving the direct

monitoring of pollutant effects by employing biological and biochemical indicators as measures of the integrated effects of pollutants on complex ecosystems. In addition, to improve knowledge of the trends in productivity of major crops and forage species, we should carry out long-term (5 to 15 years) baseline monitoring of natural, managed, and damaged ecosystems. Such an effort could include the establishment of permanent monitoring stations to monitor pollutant transport and biogeochemical cycling through biosphere sectors such as biosphere reserve sites, airsheds, river basins, and watersheds. Associated with this effort, we should monitor gross trends of environmental effects by periodically surveying indicator species.

Finally, the needs for a National Environmental Specimen Bank should be investigated. Such a data bank would allow retrospective analyses as new techniques are developed or new pollutants are identified.

With regard to **source monitoring,** we should improve our support of the regulatory efforts in several ways. First, we should expand the ability for intensive monitoring of sources to improve emission estimates and to audit self-monitoring reports. The development of rapid screening methods is essential here to discover violations. Second, to assure the quality and utility of source monitoring data, we must improve our program of certifying the laboratories that are analyzing environmental samples. Third, we must improve the monitoring of trace elements leaching into surface and groundwater supplies from industrial wastes, and of toxic substances and suspected carcinogens in air, water, and soils near major production sites. Fourth, we should conduct intensive surveys to identify all major point sources in regions having severe water quality limitations and aid in the establishment of permanent monitoring sites as necessary.

Our **ambient monitoring** program should emphasize the design and implementation of an air quality monitoring network for all criteria pollutants. Such a network should be capable of measuring fine particles. This may include measurements of size and chemical composition for sulfates, nitrates, polycyclic organics, and trace metals.

We also need to emphasize the monitoring of pollutants that are of special importance in certain areas of the country. For example, we should select effective instruments and methods to monitor visibility in western areas, especially those that may be impacted by increased exploitation of energy resources. For the northeast, north, and central portions of the United States and southeastern and south-central Canada, we should emphasize the long-term monitoring of the wet and dry deposition of pollutants. An especially important factor here is the measurement of acid precipitation. Additionally, we need to understand the role of long-range transport of hydrocarbons in ozone formation in these areas. Finally, for those regions which can be classified "pristine," we should support the design and implementation of a monitoring network to help identify any significant deterioration in the quality of the air.

Our **data analysis and linkage** programs must emphasize the standardized connection of existing data bases and the improvement of information display capabilities. Data bases containing health and employment data from the various organizations within the Department of Health, Education and Welfare should be linked, wherever cost-effective, with data bases containing environmental quality data. The latter are maintained by many agencies including the EPA, the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, the Department of Agriculture, and the Department of Energy. Linking these systems in a standardized way will allow improved capability for determining cause-and-effect relationships between environmental conditions and health effects.

To improve our ability to display and analyze this data, we should extend the capabilities to the UPGRADE system to include emissions and effluent monitoring data and morbidity data. Correlations may then be developed between pollutant emissions/concentrations and morbidity/mortality data to identify geographic areas of concern.

Our **measurement methods** program should focus on four major areas. First, we need to improve our ability to determine the detailed composition and emission rates of air pollutants from stationary and mobile sources. Particular emphasis should be placed on asbestos, carbon-containing vapors and particulates, sulfates, nitrates, and suspected mutagens and carcinogens emitted by stationary and mobile combustion sources.

Second, we need to develop advanced systems to measure water quality. We require sensors that can be automated and installed on waterborne platforms to monitor pH, dissolved oxygen, coliforms, heavy metals, oils, and grease in marine and fresh water. In addition, we need to develop remote sensing techniques (laser fluorosensors, lidar, multispectral analyses) to determine, quickly and

inexpensively, such important factors as organic loadings in streams, ocean circulation patterns, and turbidity impacts of ocean dumping.

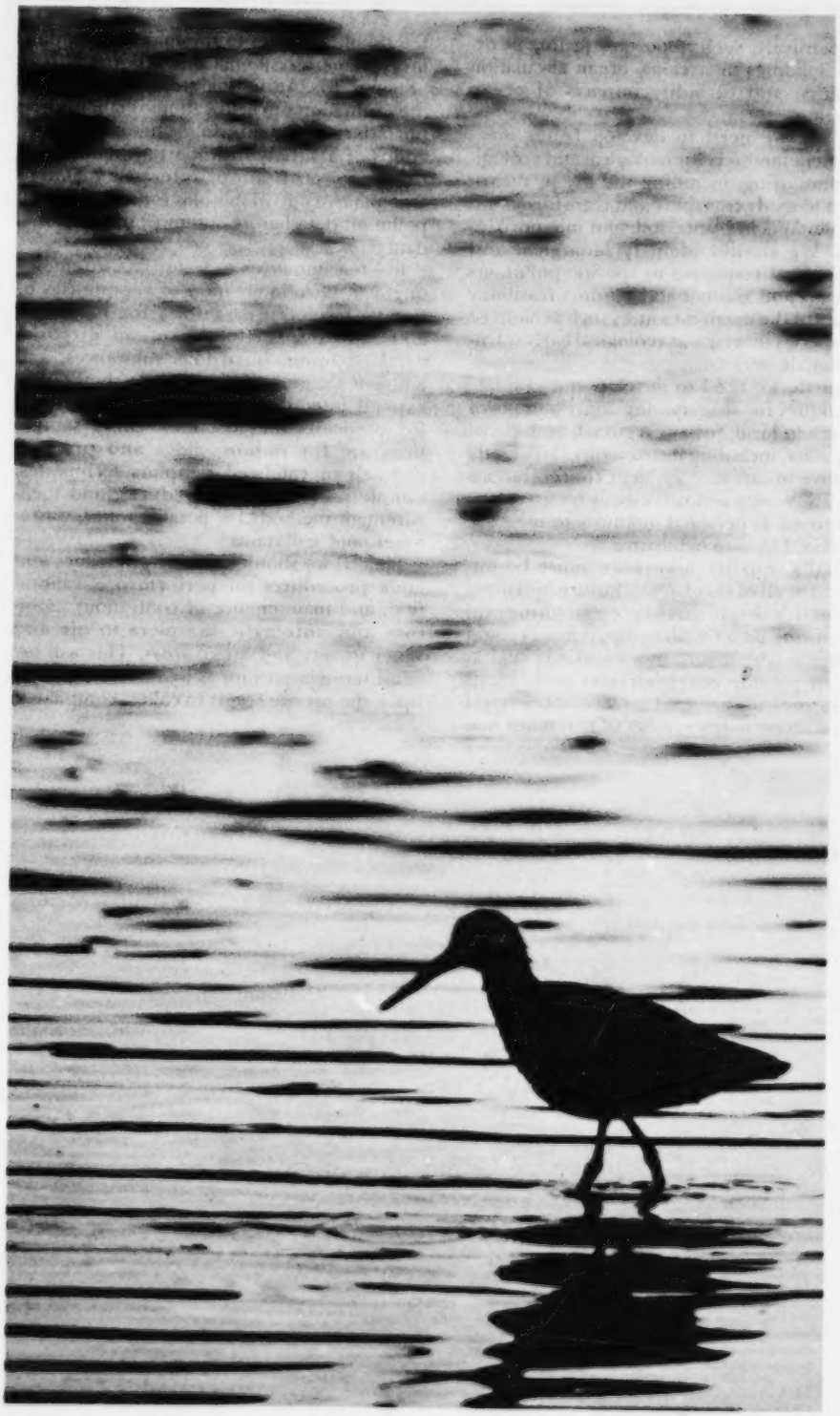
Third, we need to develop better measurement methods for biological and ecological monitoring, including the use of microcosms to study transport and transformation of pollutants in plants, soil, and microorganisms. We should identify biological and biochemical responses to specific pollutants in plants and animals and conduct feasibility studies of the use of measures such as biomass and species diversity as ecological early warning signals.

Fourth, we need to develop and evaluate techniques for determining contributions of sources to local, urban, regional, and global air quality, including instruments sufficiently sensitive to measure ambient concentrations in pristine areas and sufficiently miniaturized to be used as personal monitors to measure individual human exposure.

Finally, **quality assurance** must be enhanced in all of these areas. Future initiatives to ensure high-quality environmental monitoring data for air measurements could include establishment of a standards laboratory to provide interlaboratory calibrations for air measurements. This laboratory could assure accurate traceability of reference materials and samples to the national standard measurement system at the National Bureau of Standards. Additional steps would include the evaluation or certification of laboratories (including air monitoring stations), external audits of a variety of important monitoring programs, provision of reference materials and quality control samples for all important pollutant data before submission to national data banks.

Related initiatives in water measurements ought to include creation of repositories of standard reference samples for municipal and industrial effluents, ocean disposal, drinking water, hazardous substances, and ambient water quality uses. We should also expand interlaboratory comparison studies for pesticides and the cross-check sample program for radionuclides and produce manuals of validated sampling techniques, sample preservation procedures, and measurement methods for potable water, wastewater, and sediments.

Finally, we should provide guidelines and audit procedures for performance, calibration, and maintenance of continuous monitors and automatic samplers in air and water quality and other areas. This will become more important as we increasingly rely upon the private sector to collect compliance data.



We are particularly committed to strong measures to protect our most important resource — human health — from the increasingly apparent problem of hazardous substances in the environment.

The President's message
to the Congress
May 23, 1977

Environmental futures

In developing the topics discussed in this edition of the *Research Outlook* we relied upon three sources of guidance—recent Federal environmental legislation, computerized projections of economic and pollutant growth rates, and our best insight as scientists and researchers. Insight is difficult to document although it is, we hope, apparent in the preceding chapters. The other two sources of guidance, legislation and projected trends, are discussed in this chapter.

Legislative guidance

The majority of research conducted by EPA is done in direct support of one or more of the Agency's statutory regulatory functions (see listing). The emphasis of environmental statutes has shifted gradually over the past six years—from mobile sources and gross water pollutants to toxic substances and longer-term risks. EPA's research efforts have shifted along with this emphasis.

The major legislative emphasis is now upon protecting human health by controlling toxic substances. This, we feel, is an emphasis which will dominate our environmental research over the next five years. In his 1977 environmental message to the Congress, the President stated that "the presence of toxic chemicals in the environment (is) one of the grimmest discoveries of the industrial era." Over the last two years, the Congress has passed major environmental legislation—the Toxic Substances Control Act and the Resource Conservation and Recovery Act—as well as amendments to the Federal Water Pollution Control Act, the Safe Drinking Water Act, and the Clean Air Act.

To implement this legislation, the President has instructed EPA to give its highest priority to controlling toxic pollutants in industrial effluents under the Federal Water Pollution Control Act. The recent amendments to this Act permit EPA to move more decisively against the discharge of chemicals potentially injurious to human health. EPA has also been instructed to set standards under the Safe Drinking Water Act which will limit human exposure to toxic substances in drinking water, beginning with potential carcinogens. The recent amendments to the Clean Air Act also stress limiting human exposure to toxic substances.

The major impetus behind these efforts to control toxic substances is the need to protect human health. This theme is woven throughout EPA's authorizing legislation. Our role is protective and preventative, not curative. EPA is not mandated to treat diseases associated with pollution after they have become obvious, but rather, to prevent such harmful pollution in the first place.

The Toxic Substances Control Act (TSCA) provided the theme for this *Research Outlook*. It states, "if the Administrator (of the EPA) determines that a risk to health or the environment associated with a chemical substance or mixture could be eliminated or reduced to a sufficient extent by actions taken under the authorities contained in such other Federal laws, the Administrator shall use such authorities to protect against such risk unless the Administrator determines, at the Administrator's discretion, that it is in the public interest to protect against such risk by actions taken under this Act." With such a fundamental and comprehensive mandate, it is essential that the scientific basis for the Agency's actions to protect public health be both sound and constantly expanding in response to emerging problems.

The other recently passed environmental legislation—the Resource Conservation and Recovery Act, the Clean Air Act amendments and the Clean Water Act amendments—give specific emphasis to different aspects of research and development. On the whole, TSCA and the other acts are telling us that the nation's policy makers want us to expand that research and development which will provide new and improved scientific information about the causative relationship between pollution exposures and adverse health and environmental effects, and about the technological or other means to reduce the exposures to acceptable levels. Furthermore, the policy makers want us to concentrate on:

- —toxic and hazardous substances,
- —pollutants which expose large populations,
- —pollutants which are pervasive and persist in the environment,
- —pollutants which may have long-term health and ecological effects, and
- —pollutants which may affect large-scale, even global, processes.

Such recognition by the policy makers of the growing sophistication required to make further progress in our efforts toward preventative public health protection must be reflected in the priorities for the environmental research and development program. This *Research Outlook* reflects this important guidance.

Projected trends

In addition to legislative guidance (and to provide us with as quantitative a basis as possible for our speculations), we looked to pro-

Recent Congressional Actions

Year	Action	Effect on direction of future research
1972	Federal Water Pollution Control Act Amendments	Research and development effort has led to the development of technologies to control pollution from point sources. Attention shifting to the control of runoff from rural and urban areas and sludge management practices.
1972	Marine Protection, Research, and Sanctuaries Act	Research and development has contributed to the abatement of pollution from ocean dumping and point source discharges. Attention focusing on significance of dredge material disposal and energy development in marine waters.
1972	Noise Control Act	No substantial noise research planned for FY 1978. Future research may involve a coordinated interagency effort.
1972	Federal Insecticide, Fungicide, and Rodenticide Act Amendments	Information needed on best management practices to control pesticides in water runoff from agricultural lands.
1974	Safe Drinking Water Act	Scientific information needed upon which viable standards can be based. Improved measurement and monitoring methods needed to determine compliance with regulations.
1976	Toxic Substances Control Act	Mandated broad program of research, development and monitoring, and dissemination of technical information.
1976	Resource Conservation and Recovery Act	Research directed toward the development of improved solid waste management techniques, disposal technology, resource recovery technology, and toward information on the fate and processes of hazardous waste transport through soil and groundwater systems.
1977	Clean Air Act Amendments	Mandated program of research to determine causes and effects of ozone depletion on public health and welfare.
1977	Clean Water Act	Return flows from irrigated agriculture reclassified to a nonpoint discharge. Several sections relate to marine waters.
1977	Senate Committee on Government Operations Study on Federal Regulation	Legislation recommended placing EPA in charge of all radiation safety, thus centralizing responsibilities now distributed among 15 departments, commissions, or regulatory agencies.
1977	Environmental Research, Development, and Demonstration Authorization Act of 1978	Mandate of a separate program to conduct continuing and long-term environmental research and development.

jections from a computerized predictive model* (Ref. 1). The model is complex. It can be used to generate projections of environmental pollutant loadings 10 to 20 years hence.

Its projections, however, anticipate only those problems which can be defined, quantified, and modeled based upon today's knowledge. For example, in past years the toxic substances problem was viewed largely in terms of pollution by heavy metals. Only on this subject do we have enough data to create a realistic projection. Projections for other topics, such as organic compounds, are generally unavailable.

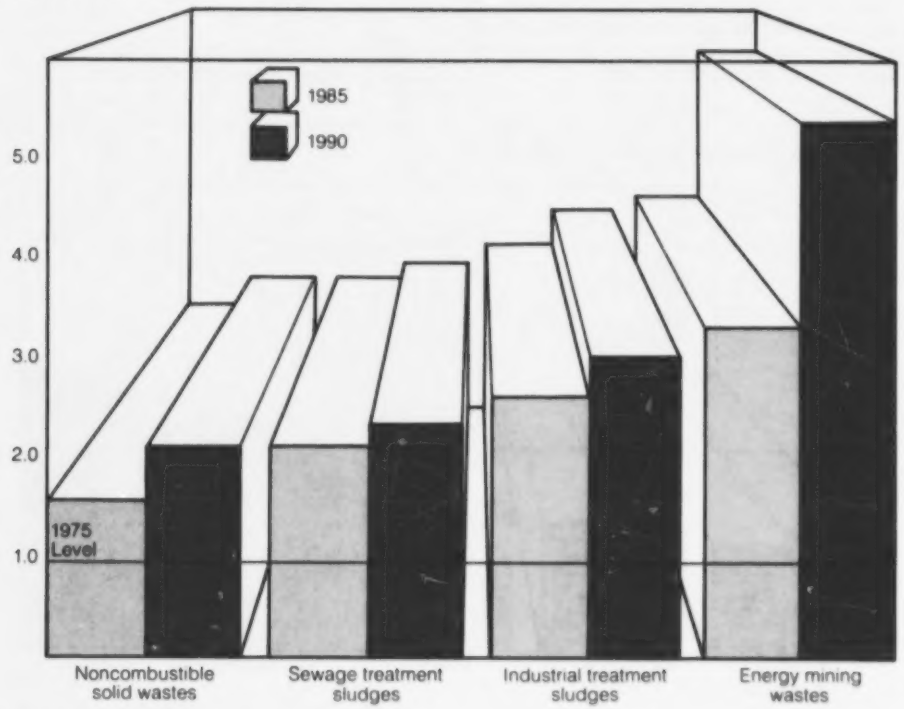
The model was used to project levels of residual substances (wastes) from various industrial activities between now and 1990. Based upon an assumed population of 245 million in 1990 and a level of unemployment of 4.6 percent in the same year, the model allows us to examine the growth of more than 350 economic sectors. For example, even with the assumed conservation emphasis in the National Energy Plan, about one and one-half times as much energy will be required by 1990. The national policy of reliance on domestic energy sources would, therefore, require the use of almost two and one-half times as much coal in 1990 as in 1975.

Many of the toxic substances of greatest concern are those produced by the nation's chemical industry. The production of that industry is expected to grow much faster than the population, and to almost double by 1990. Agricultural output, which is related to nonpoint sources of water pollution and pesticide problems, parallels our population growth. This forecast uses export trends of the early 1970's, but assumes that we will not "feed the world."

With no catastrophic energy crises, vehicle-miles traveled will grow at the same rate as the economy and faster than the population. The automobile will continue to dominate passenger-miles traveled at 83 percent of the total in 1990 as compared with 86 percent in 1975. Diesel automobiles will increasingly dominate the market (Ref. 2, 1).

*The model used was the Strategic Environmental Assessment System developed by EPA and maintained by this Agency and the Department of Energy.

Production of Solid Wastes



Source: U.S. Environmental Protection Agency, 1978

As the economy expands, pollution will increase with a growing production capacity. If best available technology advances toward zero discharge, a steady decrease in the discharge of all regulated pollutants can be achieved. However, as pollutants are removed from air or water, the resultant solid wastes must be either disposed of or used. These solid residuals can become air and water pollutants once again if improperly treated.

Increasing volumes of various solid wastes represent assets as well as liabilities. Many wastes contain toxic materials and if improperly disposed of on land, the soil and groundwater may be contaminated. On the other hand, some wastes can be an asset such as for energy and the recovery of nonferrous metals. In the case of surface mining wastes, the forecast assumes a steady increase in reclamation with a 100 percent recovery by the year 2000.

Overall trends of residuals (pollutants) discharged to air, water, and land indicate that, with existing regulation, pollution will increase by 1990. Water pollution indicators are below 1975 levels. The air pollution indicators, sulfur and nitrogen oxides, will be above 1975 levels in both 1985 and 1990 as a result of increased combustion of fossil fuels. However, automobile emission controls will lead to a downward trend in hydrocarbons and carbon monoxide in 1990.

The chosen topics

Using our three guiding principles—legislation, projected trends, and insight—we chose eight topics to be discussed in this year's *Research Outlook*. We consider these topics to be our central research concerns during the next five years and to be central to the health and welfare of our citizens.

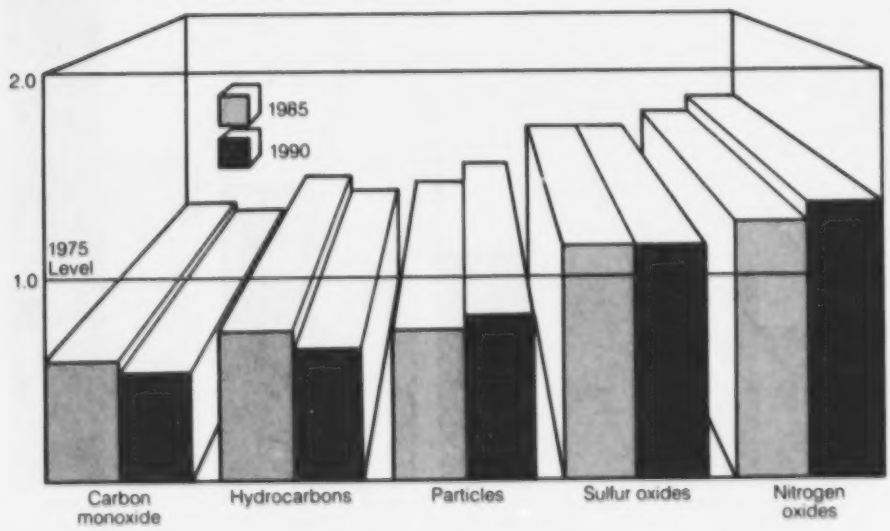
Exposure to **toxic substances** results from multiple sources (water, air, food) as they come in contact with internal tissues by breathing or eating, or by contact with the skin or senses (Ref. 3). **Air pollution** caused by sulfur and nitrogen oxides, including

Socioeconomic Trends

Factor	1985	1990
Population	1.10	1.15
Gross national product	1.55	1.80
National energy demand	1.27	1.34
Coal mined	1.93	2.41
Chemical production	1.63	1.89
Agricultural production	1.05	1.12
Vehicle miles traveled	1.54	1.77

Source: U.S. Environmental Protection Agency, 1978.

National Discharge of Air Pollutants



Source: U.S. Environmental Protection Agency, 1978.

aerosols, can aggravate pulmonary disorders such as emphysema. Air pollution can also contribute to the acidity of rain, thus damaging agricultural and forestry productivity.

The compatibility of **energy and the environment** requires research by EPA, especially associated with the accelerated development of coal reserves over the next decade. The control of **solid waste** by incineration or disposal on land can affect the quality of the air we breathe or the groundwater we drink. An increase in the Gross National Product through 1990 and a concurrent threefold increase in the generation of industrial sludges from air and water pollution control indicates a potentially serious solid waste problem.

Global pollution, brought about by emissions of carbon dioxide or by the release of substances such as fluorocarbons, may indirectly affect crop yields and skin cancer rates. Marine pollution, a part of global pollution, affects the productivity of ocean and coastal areas including the quality of food from the sea.

The increased use of telecommunication systems, radio and television transmitters, and other sources of **nonionizing radiation** such as high power radars, microwave ovens, or high voltage transmission lines poses a threat to human health. The heaviest pollution from these sources coincides with human population centers.

Nonpoint discharges such as runoff from farms, construction sites, and strip mines, are major sources of water pollution. Changes in the methods and extent of farming, increased forest production, and watershed modifications can lead to contamination of drinking and recreational waters.

The assessment of human exposure to harmful agents is limited by inadequate monitoring and the unavailability of measurement equipment. **Measurement and monitoring** will provide accurate data to characterize effects and identify pollutant transport routes.

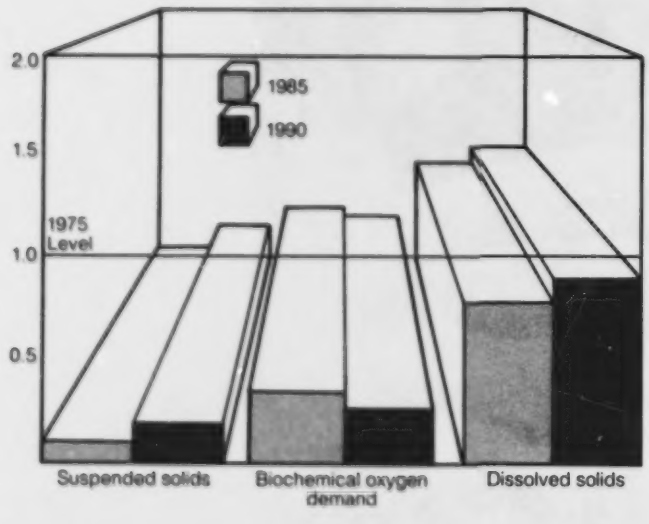
While these eight priority areas form the core of the *Research Outlook*, the list is not intended to be comprehensive. The intent is to use this report as a starting point in open discussions with the Congress, the EPA Science Advisory Board, other agencies, academia, and industry in order to develop a strong, responsive environmental research program. This *Outlook* is the basis for such a dialogue. Out of that dialogue will develop our research program. Out of that program will come the information we all need to help assure that the quality of our air, water, and food supplies is adequate to protect human health and the ecological system upon which our survival depends.

Industrial Output

Sector	Multiples of 1975 values 1985	1990
Iron and steel	1.25	1.27
Nonferrous metals	1.67	1.95
Pulp and paper	1.40	1.57
Chemicals	1.63	1.89
Electric utility	1.86	2.20
Petroleum and natural gas	1.22	1.25
Food processing	1.11	1.23
Fabrication and basic products	1.76	2.04
Coal mining	1.93	2.41
All other sources	1.62	1.90
Total output	**1.58**	**1.83**

Source: U.S. Environmental Protection Agency, 1978.

National Discharge of Water Pollutants



Source: U.S. Environmental Protection Agency, 1978.

You get what you pay for.

Gabriel Biel
Exposito Canonis Missae
1495

Research options

EPA simply cannot solve all the problems of the environment. We must establish priorities, and our first priority is to protect people. The ranking of the eight topics and the forging of their respective goals are based upon this premise.

Unfortunately, even as we address these few but very important topics, we are not addressing many other substantive problems. The importance of the other problems, however, should not be underestimated; we may very well lack only the relevant information to foresee them. This is why the *Research Outlook* must be viewed as a dynamic process where priorities and problems change each year as new perceptions emerge. The foundations for such a process are our forecasts of environmental futures and our best scientific judgment.

The Environmental Research, Development, and Demonstration Authorization Act of 1978 requires that three growth options be considered in this report. The "no growth" option assumes that the total Agency research budget remains at the Fiscal Year 1978 level through the five-year period to Fiscal 1982. The "moderate growth" option assumes a five percent growth in the total budget compounded annually from Fiscal 1979 through Fiscal 1982. This results in a Fiscal 1982 level 22 percent above the Fiscal 1978 level. The "high growth" option assumes a ten percent annual compounded growth resulting in a 46 percent increase in Fiscal 1982 over Fiscal 1978. As a point of reference, EPA's research budget for Fiscal 1978 was $297 million. For Fiscal 1979, the Agency has submitted a budget request of $306 million to Congress.

In the following sections, the implications of our priority rankings (presented in the preceding chapters) and the budget growth options are blended together. In developing this picture of our research program over the next five years, we have taken into account the relative size and maturity of our current research efforts in the eight areas, as well as the new emphases called for in this *Research Outlook*. For example, new areas such as **toxic substances** and **nonionizing radiation** now comprise only minor fractions of our research efforts—one percent or less—but must grow if we are to meet the challenges outlined in the preceding chapters. On the other hand, relatively mature areas such as **energy and the environment** and **air pollution** now represent major shares of the program—44 and 14 percent, respectively—and offer considerable potential for redirection of ongoing efforts to higher priority emphases.

Toxic substances

Prediction and control of toxic substances are our highest research priorities. Although toxic substances research currently represents only about one percent of EPA's research funding, EPA Fiscal 1979 budget submission calls for an almost threefold increase in this research. By Fiscal 1982, even under a no growth option, EPA plans to expand funding of research on toxic substances to about 6.8 times its current level or $25 million. Under the high growth option, funding would increase nearly thirteenfold over the Fiscal 1978 to a level of $48 million.

Air pollution

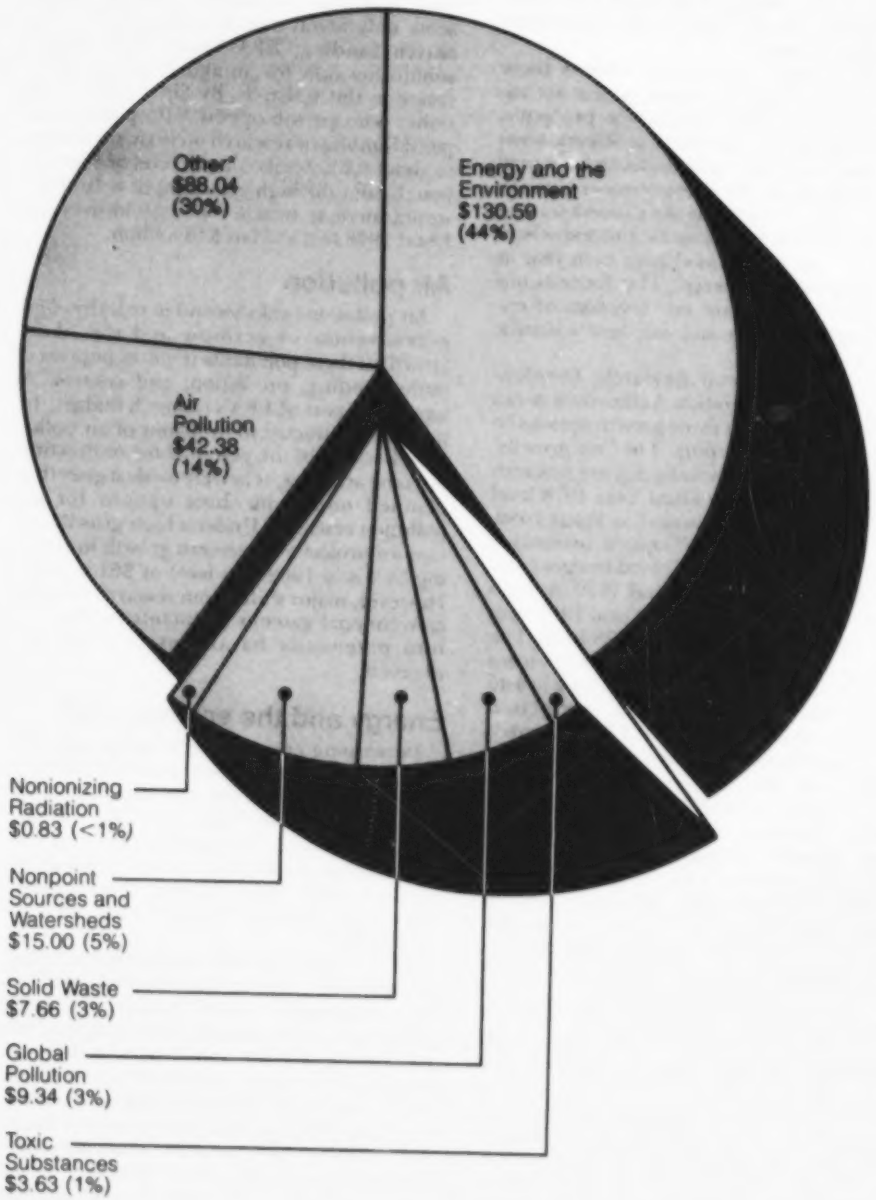
Air pollution ranks second in priority. The pervasiveness of aerosols and the likely growth of these pollutants requires improved understanding, prediction, and control. A significant part of EPA's research budget, 14 percent, is directed to problems of air pollution. Because of the potential for redirecting ongoing activities, relatively modest growth is planned under the three options for air pollution research. Under a high growth option we project a 50 percent growth in funding by Fiscal 1982 to a level of $61 million. However, major shifts from research into the conventional gaseous pollutants to research into potentially hazardous aerosols are planned.

Energy and the environment

Developing energy sources while protecting the environment ranks third in priority, primarily because of the potential impacts of increased coal combustion on air quality. During the next 20 years, preventing environmental problems through anticipatory research will be more effective than regulating energy sources after problems are well entrenched.

EPA already provides substantial funding for research to assure an adequate supply of environmentally "clean" energy. By 1982, prediction and control of particulate and sulfur oxide pollution should be well defined. Control of nitrogen oxides from power plants should also be better understood by that time. By Fiscal 1982, we anticipate a shift of funding to other areas of research, while still maintaining substantial energy funding. A no growth budget would result in a 30 percent decrease by Fiscal 1982 to a level of $103 million as compared with Fiscal 1978. A high growth total budget would reflect a ten percent decrease to a level of $117 million for energy related research.

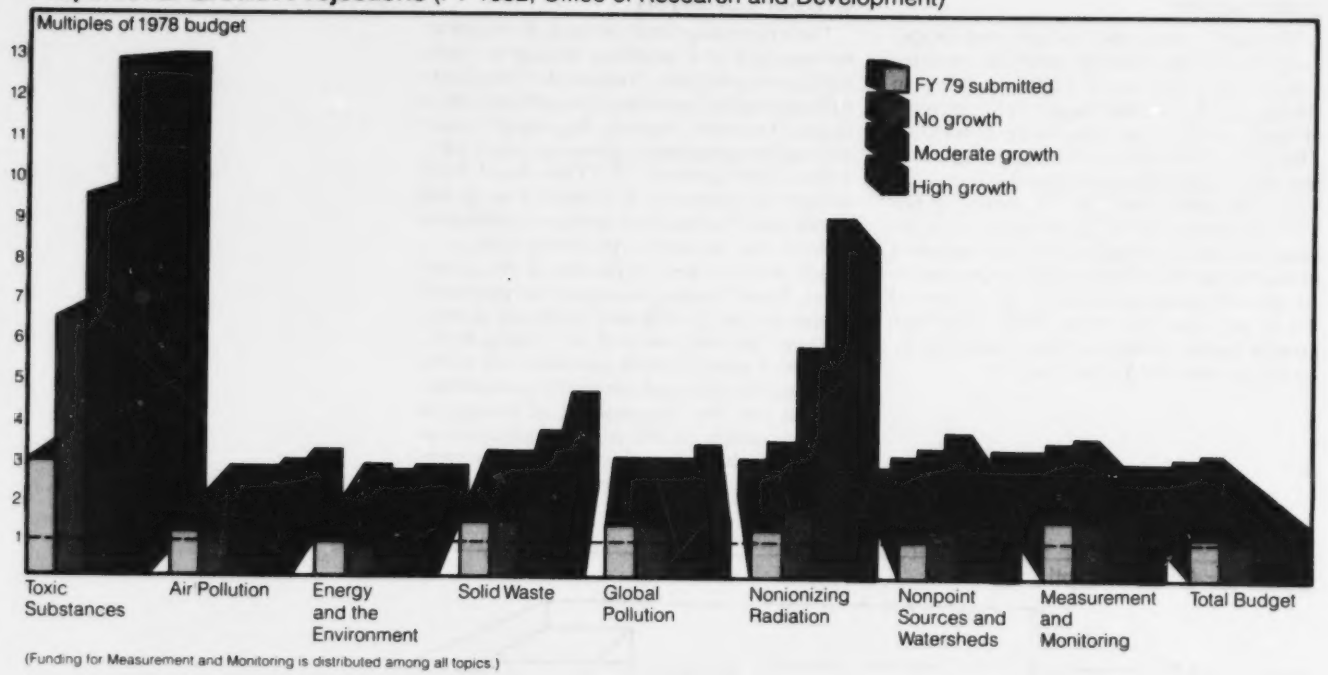
FY 1978 Budget ($297.47 million)
Office of Research and Development (Millions of dollars)



Notes:
*Includes drinking water, point sources of water pollution, pesticides, interdisciplinary research, and program management

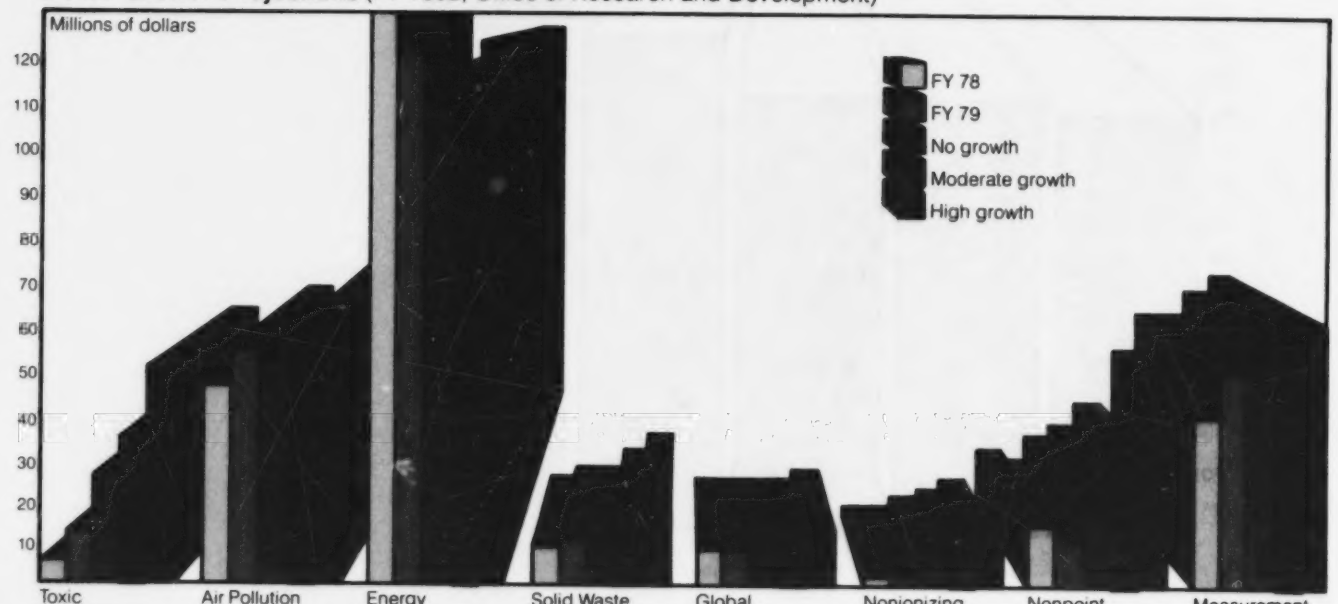
Fiscal year 1978 funding of $37.32 million for Measurement and Monitoring is distributed among all topics.

Proportional Growth Projections (FY 1982, Office of Research and Development)



(Funding for Measurement and Monitoring is distributed among all topics.)

Dollar Growth Projections (FY 1982, Office of Research and Development)



(Funding for Measurement and Monitoring is distributed among all topics.)

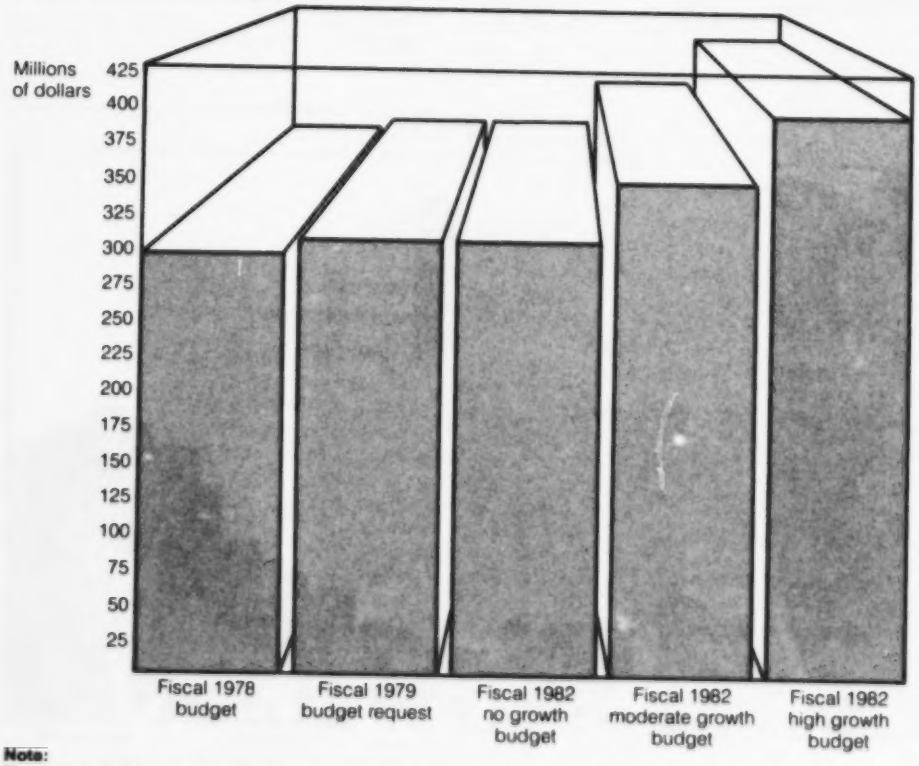
Solid waste

The significant growth in solid waste, especially hazardous industrial materials, requires that we place our fourth highest priority on solving problems in the disposal and recovery of such wastes. Less than three percent of EPA's Fiscal 1978 research budget is spent on investigating problems with, and ways to control, solid waste. A 40 percent growth by Fiscal 1982 under the no growth option is the same level of $11 million EPA has requested of the Congress in Fiscal 1979. In the moderate growth option, an increase by a factor of 2.2 is projected by Fiscal 1982. The high growth option would call for a threefold increase to a level of $23 million.

Global pollution

Understanding what we must do to assure the survival of a healthful biosphere ranks fifth in our priorities. Prediction of the effects of human activities on the atmosphere and on ocean resources requires improved knowledge of the biosphere's processes and cycles. About three percent of EPA's Fiscal 1978 budget for research is dedicated to global problems. This research addresses primarily coastal and estuarine problems and, to a much lesser extent, depletion of the ozone layer. Small funding increases are projected under the no growth and moderate growth options. We will, however, be looking to the efforts of other Federal agencies such as the National Oceanic and Atmospheric Administration and the Department of Energy to provide much of the needed information. Under the high growth option a 50 percent funding increase is projected to a level of $14 million.

Basis for Growth Options



Note:
The three budget options (no growth, moderate growth, and high growth) are based on growth from the Office of Research and Development FY 79 budget submission compounded annually (respectively at zero, five and ten percent).

Nonionizing radiation

The subtle nonthermal effects of nonionizing radiation and the likely growth in the importance of this potential health hazard require that we make this area our sixth priority. EPA's research funding for the effects of nonionizing radiation amounts to considerably less than one percent of EPA's research budget. Modest budget increases in this area appear as large percentage increases relative to the Fiscal 1978 base. The nonionizing radiation research area would double under the no growth option to $2 million, increase nearly fivefold under the moderate growth option to $4 million, and increase over eightfold under the high growth option to $7 million.

Nonpoint sources and watersheds

Research on nonpoint sources and watersheds ranks seventh in priority. The ability of watersheds to assimilate pollution is certainly limited. We must, therefore, learn how to predict and control the effects of nonpoint sources on water quality and land productivity. Research on nonpoint sources and watersheds comprises five percent of EPA's Fiscal 1978 research budget. Funding for this area declined in EPA's Fiscal 1979 submission to the Congress. By Fiscal 1982, however, we project some growth under both the no growth and moderate growth budget options, with a doubling of the budget under the high growth option to a level of $30 million.

Measurement and monitoring

Measurement and monitoring research is our eighth highest priority in this *Research Outlook*. Comprehensive measurement and monitoring of the multitude of environmental pollutants will be expensive but we must continue to steadily expand our activities in this area in order to support our efforts in the other seven priority areas. At present the funding in this area, which cuts across many of the above topics, accounts for over 12 percent of EPA's research budget. EPA's Fiscal 1979 budget submission provides for a significant 40 percent increase in measurement and monitoring to a level of $52 million. Under the no growth option the Fiscal 1979 level would be maintained through Fiscal 1982. Funding for the area would increase by 60 percent under the moderate growth option to a level of $59 million, and 70 percent under the high growth option relative to Fiscal 1978 to a level of $63 million.

Other environmental research

Since EPA supports only a fraction of the Federal environmental research efforts, we must draw extensively upon related efforts by other Federal agencies, the private sector, and other nations. Because EPA's priorities emphasize protecting public health, we can develop special relationships with some agencies through such mechanisms as the Interagency Regulatory Liaison Group. But, because of resource limitations, we cannot support all types of related research in environmental science and technology. Other organizations which focus specifically on the atmosphere, oceans, and natural resources support important research related to EPA's areas of specialization.

We have an excellent foundation on which to build. As described in the appendices on interagency and international coordination, there already exist many mechanisms for sharing of research information and conducting cooperative projects, both in the United States and in foreign countries.

We should expand our efforts to utilize the scientific information developed by other organizations. We should support their efforts to expand research capabilities where the research will complement our activities. We should share our growth potential with these organizations and should share in their opportunities as well.

Interagency coordination

1

Goals

The goals of the interagency coordination efforts are to improve both the efficiency of Federally funded environmental research and its relevance to the protection of human health and environmental quality.

Approximately three-fourths of the environmental research funded by the Federal government is performed by agencies other than the EPA. The EPA, however, requires much of the information developed via such efforts to fulfill its regulatory mission. Access to this data, and improved programming of research efforts to avoid duplication of effort or information gaps, is achieved through a multitude of formal or *ad hoc* ties between EPA and other agencies or interagency commissions.

At present, EPA's Office of Research and Development maintains formal coordinating linkages with 39 other Federal agencies and departments and is co-funding more than 200 projects each year with those agencies. These projects range from health effects studies and technology development to monitoring support and data assessment. They reflect areas of current and future interest to the agency such as toxic substances, energy, global pollution, health effects, nonpoint discharges, nonionizing radiation, and monitoring.

Toxic substances

The Toxic Substances Control Act specifically requires coordination with other Federal laws in preventing risk of injury to human health or the environment from toxic substances. The Interagency Regulatory Liaison Group (IRLG) was created by the agency heads to coordinate research and enforcement activities. The IRLG is composed of EPA, the Food and Drug Administration, the Occupational Safety and Health Administration, and the Consumer Product Safety Commission.

Under the auspices of the IRLG, significant studies are being undertaken to identify and eliminate any unnecessary duplication of effort and to identify areas where additional research is necessary. As part of its role in this exercise, EPA has initiated specific research to meet the needs of the other three agencies as well as its own. Such research includes the development of short-term *in vitro* tests and tissue bioassays, epidemiology of cancer incidence in workers and guidelines for conducting such studies, and the compilation of data on body burden of toxic chemicals. In addition, EPA is supporting development of a project level information base to meet the needs of the IRLG.

EPA maintains strong support of other Federal research agencies such as the National Center for Toxicological Research. More than $4 million of EPA funds is allocated each year to aid research at the facility. In like manner, $4 million of the 1978 budget of the National Cancer Institute has been allocated to joint National Cancer Institute and EPA research on pollution/cancer relationships.

Much of the research conducted by the National Institute of Environmental Health Sciences (NIEHS) is related to effects of toxic substances. EPA reviews the Institute's research projects and EPA and NIEHS scientists maintain close communication in the Research Triangle Park facility. Finally, EPA is funding an interagency agreement at the Center for Disease Control in Atlanta to develop epidemiological data on toxic metals.

Energy

EPA's Interagency Energy/Environment Research and Development Program is one of the largest and most successful programs of its type ever conducted by the Federal government. It relies on the close cooperation and communication among more than a dozen Federal agencies and departments. Approximately $100 million per year in energy-related environmental research and development is conducted under this program, which funds more than 600 projects. One-fourth of these projects are implemented by agencies other than the EPA, and most of the remainder are conducted by EPA-monitored extramural grants and contracts.

The Interagency Program was initiated in Fiscal Year 1975. It is based upon reports presented by two multiagency task forces in November 1974. These reports, along with guidance provided by the Office of Management and Budget and the Council on Environmental Quality, helped to establish EPA as central planner and coordinator of the entire Interagency Program.

EPA's role as program coordinator assures consideration of national environmental goals and energy development needs. A prime example of this role is the relationship that has developed between the Department of Energy and the EPA with regard to the development of synthetic fuels from coal. Under the auspices of the Interagency Program, EPA is cooperating with the Department to monitor and assess the pollutants

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from prototype and demonstration synthetic fuel plants being developed in this country.

Working with the Tennessee Valley Authority (TVA), EPA has sponsored several research projects aimed at further improving the economics and applicability of various techniques for disposing of flue gas desulfurization sludges. Additional work funded at TVA via the Interagency Program involved testing of alternative flue gas desulfurization systems under different operating conditions.

For several years, EPA's Interagency Program has been a major source of support for the nation's coal cleaning development program within the Bureau of Mines and elsewhere. The limits of cleanability of hundreds of different types of domestic coals have been tested. Major studies have also analyzed the potential economic benefits of combining coal cleaning with partial scrubbing of flue gas to achieve levels of control comparable to total scrubbing systems.

To determine what happens to energy-related pollutants in the atmosphere, the Interagency Program has combined the efforts of EPA, the Department of Energy, the National Bureau of Standards, the Tennessee Valley Authority, and the National Oceanic and Atmospheric Administration (NOAA) on various aspects of the problem. For instance, under the auspices of the Interagency Program, NOAA maintains a full-time modeling group at EPA's Environmental Sciences Research Laboratory in North Carolina.

One of the more successful interagency efforts to date has been the development of inexpensive combustion modification technologies and techniques which promise to reduce the amount of nitrogen oxides emitted by industrial and commercial boilers. These techniques promise not only to reduce pollution from a vast array of stationary pollution sources, but also to improve the overall energy efficiency of the units in the process. Closely associated with this work has been the development of various mechanisms, including advanced scrubber systems and baghouses, for removing the major pollutants from coal combustion such as sulfur oxides, particles, and nitrogen oxides.

As the Interagency Program continues to prove to be a successful means of linking the efforts of various agencies involved in energy-related environmental research, it expands its list of participants. For example, a formal memorandum of understanding has been signed with the Electric Power Research institute, a utility-funded energy research organization. In addition, both the Nuclear Regulatory Commission and the U.S. Coast Guard have indicated an interest in becoming formal participants.

Research efforts within the program will continue to focus on resolving the health and environmental problems associated with near and mid-term domestic energy resource development. The extraction, processing, and combustion of coal will continue to be a major concern of the program's efforts. Focus of this research is gradually shifting toward the identification of the health and environmental effects of energy-related pollutants. This is especially true of cases in which the pollutants may interact with other air or water pollutants, or may expose populations to small doses over extended time periods. Information gained from the longer term projects supported by the Interagency Program will help to improve the precision of the energy/environment decision-making process.

The Great Lakes

In addition to our cooperative efforts with the International Joint Commission on the Great Lakes, EPA also works closely with the National Oceanic and Atmospheric Administration, the Great Lakes Basin Commission, and the Great Lakes Fisheries Commission to share information and coordinate research. In one effort, EPA and the Great Lakes Environmental Research Laboratory of NOAA model near-shore processes and hydrodynamic transport.

EPA's Large Lakes Research station maintains the data base for the Great Lakes research community, including Federal and state agencies, as well as academic institutions and Canadian agencies. The Agency, therefore, serves as a resource and as a focal point for interagency data exchange and information management.

Atmospheric and climatic effects

As requested by the Federal Committee on Science and Technology, the EPA has taken the lead in a multiagency program called Biological and Climatic Effects Research Program (BACER). This program involves six other agencies in modeling and measuring stratospheric phenomena and their potential biological effects. For further information on this program, see the *Global Pollution* chapter.

In addition, EPA through a long standing interagency agreement with NOAA, receives meteorology support. EPA accommodates 50 NOAA employees within its organization and facilities.

Health effects

EPA maintains close contact with the NIEHS. EPA's Assistant Administrator for Research and Development is a member of the National Advisory Environmental Health Council which advises NIEHS on extramural research, primarily relating to cancer and health effects. The Agency also provides the Institute with descriptions of EPA health-related research projects.

Likewise, EPA works with an interagency task force, organized by Congressional request, to examine the needs, goals, and resources appropriate to the NIEHS research program for the next five to eight years. EPA is also participating in various working groups created to implement recommendations made by the task force.

In response to Section 402 of the Clean Air Act Amendments, the Administrator of EPA chairs a task force on environmental cancer and heart and lung disease. The National Cancer Institute (NCI); the National Heart, Lung, and Blood Institute (NHLBI); the National Institute of Occupational Safety and Health (NIOSH); and NIEHS are members of the group. The objectives of the task force are to recommend and coordinate comprehensive research on the relationship between environmental pollution and human cancer and heart and lung disease, and to recommend strategies for eliminating the risks of cancer and other diseases associated with environmental pollution.

The Agency also maintains an interagency agreement with the Center for Disease Control (CDC). The Center provides EPA with support on epidemiology studies and emergency episodes such as the carbon tetrachloride spill on the Ohio River last year.

EPA is working with NIOSH to develop studies on the effects of diesel exhausts. For some time now, NIOSH has been studying miners' exposure to diesel exhaust. Current efforts will be directed toward other areas where there is a high level of exposure, such as in locomotive terminals and bus stations.

EPA is also contributing to epidemiological studies conducted by the Food and Drug Administration and the National Cancer Institute. These agencies are studying the incidence of bladder cancer and its relationship to saccharin intake. Water supply and tap water samples are also being analyzed to determine whether there may be other carcinogens in water contributing to bladder cancer.

Finally, EPA participates in several health-related task force and advisory panels such as the Army Science Advisory Panel and Steering Committee on Primate Use.

Nonpoint sources and watersheds

To assess tools and management practices for controlling nonpoint source pollutants generated by forest management practices, EPA conducts cooperative research efforts with the U.S. Forest Service. With the Agricultural Research Service, EPA works to evaluate the effectiveness of irrigation systems. In addition, a university-EPA-Department of Agriculture coordinating committee for environmental quality research and development has worked since

Interagency Research and Development Coordination

Department or Agency	Air Pollution	Water Pollution	Energy	Pesticides & Toxics	Radiation	Health Effects	Other[a]
Agriculture		○ ▲	▲	○ ▲			
Federal Research Science and Education Administration	○ ▲	○ ▲	▲				
Food Safety Quality Service				○ ▲			
Commerce					○		
National Bureau of Standards	○ ▲	○ ▲	○ ▲		○ ▲	○ ▲	
National Oceanic and Atmospheric Administration	○ ▲	○ ▲	○ ▲				
Defense	○ ▲	○ ▲			○	○ ▲	○ ▲
Corps of Engineers		○					
Energy	○ ▲	○ ▲	○ ▲		○ ▲		○ ▲
Health, Education, and Welfare							
Public Health Service				○	○	○	
Food and Drug Administration	○	○ ▲		○	○	○ ▲	
Bureau of Radiological Health						○	
National Center for Toxicological Research				○ ▲		○ ▲	
National Center for Health Statistics	▲	▲				○ ▲	
Disease Control Center				○ ▲		○ ▲	
National Institute of Occupational Safety and Health			○ ▲	○ ▲		○ ▲	
National Cancer Institute	○ ▲			○ ▲		○ ▲	
National Heart, Lung, and Blood Institute						○ ▲	
National Institute of Environmental Health Sciences	○	○	○ ▲	○ ▲		○ ▲	
Housing and Urban Development	○ ▲	○ ▲	▲	○ ▲		○ ▲	
Interior	○	○	▲				
Fish and Wildlife Service		○ ▲	▲				
Bureau of Land Management		○ ▲					
National Marine Fisheries Service		○ ▲	○ ▲		○ ▲		
United States Geological Survey		○ ▲	▲				
Heritage Conservation and Recreation Service							
Labor				○		○	
State	○	○					○
Transportation	○						○
Federal Aviation Administration	○						○
United States Coast Guard		○			○ ▲		
Other Agencies							
Council on Environmental Quality	○ ▲	○ ▲		○ ▲		○ ▲	
National Aeronautics and Space Administration	○ ▲	○ ▲	▲		○		
Consumer Product Safety Commission	○			○		○	
Tennessee Valley Authority	○	○ ▲	○ ▲				
National Science Foundation	○	○ ▲		○ ▲			
National Academy of Sciences/National Academy of Engineering	○	○					
Nuclear Regulatory Commission	○	○ ▲	○			▲	
Great Lakes Basin Commission		○					

[a]Including noise, solid waste, and policy research.

○ Coordination through committees.

▲ Coordination through joint research.

1972 to prevent duplication of research efforts and to assure that major environmental research needs are satisfied.

EPA's activities include periodic meetings with counterparts at other agencies including the Economic Research Service and the Cooperative State Research Service to assure that the other Federal agencies consider environmental protection when planning their research.

In addition to the Interagency Energy and Environment Research and Development Program, EPA conducts joint energy-related research efforts with the Nuclear Regulatory Commission to design studies on licensing procedures; the National Marine Fisheries Service on the effects of power plant effluents; and the Department of the Interior on a siting and operations committee.

Marine pollution

To improve our understanding of the impact of human activities on the ocean, EPA participates in several interagency cooperative research efforts. For example, EPA conducts research into ocean-borne pesticides with the Bureau of Sports Fisheries and Wildlife. The Agency also coordinates with the Food and Drug Administration in studies of shellfish pollution, as well as with the Interior's Bureau of Outdoor Recreation in the selection of study sites, the Army Corps of Engineers for the measurement of water quality, and the National Science Foundation for evaluation of water quality indicators. We are also engaged in modeling the transport and fate of pollutants in the marine environment with NOAA, U.S. Geological Survey, and the Bureau of Land Management.

A joint EPA-Army Corps of Engineers technical committee coordinates research on the regulatory aspects of dredging. It recommends research studies and establishes joint projects.

We are engaged in interagency research on the impacts and cleanup of oil spills. EPA, the Department of the Interior, NOAA, and the U.S. Coast Guard are developing an oil spill damage assessment program. This program includes preparation of a report with NOAA on the Argo Merchant Oil spill; cooperation with the Bureau of Land Management in reviewing outer continental shelf documents; and co-sponsorship of an oil conference with the U.S. Coast Guard, Bureau of Land Management, NOAA, Department of Energy, and Office of Naval Research. EPA also uses U.S. Navy facilities to do research in the characteristics and effects of drilling mud.

Nonionizing radiation

Centralized coordination has resulted in complementary research and information exchange among the several Federal agencies addressing nonionizing radiation. Each agency has specific areas of responsibility in studying nonionizing radiation. EPA is concerned primarily with the centralized gathering of data for exposure standards. The Department of Commerce's Office of Telecommunications Policy coordinates Federal programs on biological effects. Other agencies conducting research are the Department of Defense and the U.S. Public Health Service's Bureau of Radiological Health.

EPA interacts with the other agencies through program reviews and research discussions on nonionizing radiation effects, including the immune defense system and genetics. In 1977, representatives from the Department of Energy discussed with EPA possible effects from a proposed Satellite Power System that would produce power from solar energy. The EPA also prepared a report section on radiation research needs for the National Institute for Environmental Health Science's research program.

Monitoring

A fundamental problem in environmental management has been the fragmentation of the nation's environmental monitoring efforts. For example, data collected by the Food and Drug Administration on pollutant levels in foods, the U.S. Department of Agriculture on levels in soil, and the U.S. Geological Survey on levels in water, cannot be synthesized due to gaps in collection, incompatibility of data storage techniques, and differences in methods of analysis.

Future coordination will be necessary in three areas of monitoring: linkage of environmental monitoring data with health effects data, ecological (or biological) monitoring, and state monitoring programs for air and water quality.

A major function of coordinated national environmental monitoring would be the linkage of environmental data with medical and socioeconomic data to establish correlations for further analysis.

EPA has taken some recent steps to promote greater interagency coordination among collectors of health and environmental data. For example, EPA and the National Center for Health Statistics agreed to work toward correlating the Center's mortality and morbidity data with EPA's environmental data. The recent formation of the Inter-

agency Regulatory Liaison Group also shows promise of improving environmental and health data collection analysis.

Biological monitoring data presently suffer from the lack of centralized storage and retrieval systems. In response to this problem, EPA has developed a computerized system (limited at present to aquatic data) now being operated on a pilot basis. Cooperation by other agencies in further development could assure a valuable interagency resource for biological monitoring data.

Another problem associated with biological monitoring is the lack of standardized sample collection, preservation, and analysis techniques. This lack can, and often does, preclude the comparison of data from different agencies. EPA is engaged in programs to produce guidelines for standardized biological laboratory procedures. Nationwide implementation of such guidelines should improve the comparability of biological measurement data.

In the near term, a major coordination effort is needed to provide guidance to the states in establishing and operating air and water monitoring systems to meet requirements of EPA regulations and standards. Quality assurance guidance provided to the states through EPA's ten regional offices covers the use of approved measurement methods, quality control techniques and materials, and audits of data and system performance. Efforts are underway to prevent duplication of activities and to provide uniform guidance to state monitoring programs for ambient air, stationary sources, and drinking water analysis.

In addition to these activities, EPA's laboratory in Las Vegas, Nevada, is conducting radiation monitoring for the Department of Energy. EPA also has agreements with the National Aeronautics and Space Administration for aircraft monitoring, monitors the marine environment with the assistance of U.S. Coast Guard vessels, and shares sampling stations with the National Marine Fisheries Service.

Of particular importance this year is the launching of a new program with the National Bureau of Standards to develop calibration materials, measurement methods, and standards for research monitoring. This program is similar to the Interagency Energy/Environment R&D Program mentioned earlier.

International coordination

2

Goals

The goals of our international activities are to recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States, lend support to initiatives, resolutions, and programs designed to improve international cooperation in anticipating and preventing a decline in the quality of our global environment.*

The Office of Research and Development currently conducts, and will continue to pursue, a high level of cooperative and coordinated research with other nations and international organizations. The benefits of these activities are threefold. First, some of the problems we face, such as depletion of the ozone layer or protection of the Great Lakes, are inherently international, and a unilateral approach to their solution would be inadequate. Second, just as our technology is superior in some areas, other nations have areas of experience and expertise which allow for an efficient, mutually beneficial sharing of information. Third, the reduction or elimination of pollution anywhere on the globe is, in a larger sense, of benefit to all who live on this planet. As we improve and share our pollution control technologies, our entire environment becomes a more healthful place to live.

EPA specialists participate in joint projects under bilateral agreements with Canada, the Federal Republic of Germany, Japan, Mexico, the USSR, and excess foreign currency countries (e.g., Egypt, Poland, Yugoslavia, Pakistan, and India). EPA also participates in working groups associated with multilateral organizations such as the Organization for Economic Cooperation and Development, NATO's Committee on the Challenges of Modern Society, United Nations Environmental Program, World Health Organization, Pan American Health Organization, Commission of European Communities, and the Economic Commission for Europe.

To gain insight into contemporary domestic issues by learning from another's experience, EPA researchers participate in fact-finding missions, attend international symposia, and provide advice to those countries requesting assistance in solving their own environmental problems.

Agency participation in ongoing international activities reflects areas of current United States concern for potential environmental problems and emphasizes toxic substances, atmospheric pollution, water pollution, hazardous wastes, energy, and monitoring.

*Wording adapted from Section 102(2) (E) of the National Environmental Policy Act (NEPA).

Toxic substances

Issues relating to toxic substances, including multimedia exposure to environmental chemicals and related health effects, significant perturbations to ecosystems, and disposal of toxic substances, are of primary concern to environmentalists worldwide. Therefore the Agency is working on several international initiatives in this area.

Implementation of the Toxic Substances Control Act requires cooperation in establishing international agreements on regulatory procedures (e.g., consistent testing requirements, agreed quality control procedures, standard methods).

The Agency is concentrating its efforts within major international organizations such as the Chemicals Group of the Organization for Economic Cooperation and Development (OECD). EPA is participating actively in the chemical testing program of the Chemicals Group to harmonize test methods and systems to predict the effects of substances on humans and the environment before substances enter the marketplace. EPA's focus is on methods for testing the long-term effects of chemical substances on human health.

EPA is discussing with the European Commission the administrative details of toxic substances control, including the harmonization of the Toxic Substances Control Act premanufacturing procedures and the examination and evaluation of toxicity testing. Also in cooperation with the World Health Organization, EPA will help develop an international plan of action to improve the evaluation of health risks from exposure to chemicals.

Japan has long been concerned with the issue of toxic substances. Under a United States-Japan bilateral agreement, EPA has exchanged information in such areas as mercury removal from contaminated wastewater and sludges, DDT and PCBs in accumulated sediments, and the fate and effects of toxic substances in sediments. Areas for future cooperation may include studies on chemical incidents, sharing of test information, risk assessment evaluations, chemical import/export controls, and the establishment of an international convention to control toxic substances.

The Japanese are also knowledgeable in the area of removal and disposal of toxic sed-

iments. They have initiated full scale remedial programs in several harbors and bays in Japan. Their dredging technology, which attempts to keep aquatic environmental damage to a minimum, could have direct applicability to the PCB and Kepone situations in the United States. Recently, an EPA-Corps of Engineers team coordinated an evaluation of this dredging technology.

EPA is also cooperating with the Federal Republic of Germany in a study of methods for, and the feasibility of, environmental specimen bank operations. The objective of such a specimen bank is the long-term storage of biological specimens and data for future analysis to determine the historical record of pollutant burdens.

Atmospheric pollution

Atmospheric pollution is a major area for international consideration because airborne pollutants can travel across national boundaries, continents, and oceans. Research on transport and transformation and biological and health effects of air pollutants is, and will continue to be, an important aspect of EPA's international program.

The United States and Canada have an increasing number of cross-boundary air pollution problems that require analysis and resolution through bilateral contact or reference to the International Joint Commission. At present, there are at least eight major stationary source pollution problems between the two countries, none of which is amenable to easy solution. The major need in each problem area is for better information on the potential impacts of sources and their effects on health and welfare in both countries. EPA has been assisting the Department of State and the Joint Commission in making these assessments. In addition, EPA has offered to hold a joint United States-Canadian workshop in 1978 to begin a harmonized research effort on long-range pollutant transport. In addition, EPA and Environment Canada are working closely on problems of mobile source air pollution, principally to foster the more than $18 billion annual trade in our integrated automobile manufacturing and marketing structure.

EPA also works under a United States-Mexico Agreement to study the transport and effects of air pollutants across the border. EPA and Mexico's Subsecretariat for Environmental Improvement are now formulating a Memorandum of Understanding to establish a formal exchange of information, training, and surveillance. It is expected that this joint United States-Mexico program will assist the Mexican government in the design and implementation of air monitoring network systems, including a quality assurance program, so that data collected in Mexico are comparable to United States data. Future activities may include joint studies to determine the transport of air pollutants across the border in both directions and to work out mutually agreeable control programs. At present, two metropolitan border areas, San Diego-Tijuana and El Paso-Ciudad Juarez, are receiving primary attention and joint programs are being initiated at both the national and local levels. In addition, EPA may assist the Mexican Secretariat for Human Settlements in developing a system for evaluating environmental impact using remote sensing as well as ground level measurement techniques.

EPA currently assists the Economic Commission for Europe's Steering Body on Long Range Transport of Air Pollutants in the study of sources, transport, and fate of sulfur oxides. In the near future, nitrogen oxides will be included in such studies.

Under the United States-Japan bilateral agreement, researchers of Japan and EPA are exchanging information on meteorology, photochemical air pollution, and in particular, air pollution conditions that lead to production of photochemical oxidants (smog). The Japanese are shifting their oxidant control strategy from nitrogen oxide control alone to nitrogen oxide control combined with hydrocarbon control. Information from each country's air pollution studies including diffusion modeling, analysis, and field measurements should, in the future, improve our understanding of air pollution movement, our ability to forecast air pollution concentrations, and our stationary source air pollution control technologies.

Under US-USSR Environmental Agreement, the Agency is concerned with two major areas: air pollution modeling and measurement, and stationary source air pollution control technology. A joint wind tunnel experiment is planned to simulate the distribution of air pollutants over a specified complex terrain, and a joint field experiment in the USSR to study the formation and transformation of natural aerosols will be conducted. These two activities will aid both countries in understanding basic air pollution processes.

An excellent example of international cooperation in the area of health effects is the ongoing Isotopic Lead Experiment sponsored by the Common Market, Italian Federal Hydrocarbon Authority, and International Lead and Zinc Research Organization. Under this study, gasoline stations in the To-

Worldwide Environmental Activities

Organization/Activity	Research, Development, and Demonstration Programs							
	Air Pollution[a]	Water Pollution[b]	Radiation	Pesticides	Noise	Waste Mgmt[c]	Toxic Subst	Energy
International Organizations								
Commission of European Communities (CEC)	•	•			•	•	•	
Committee on Challenges to Modern Society (CCMS)	•	•				•		•
International Organization for Legal Metrology (OIML)	•	•	•	•	•	•	•	•
International Standards Organization (ISO)	•	•	•	•	•	•	•	•
Organization for Economic Cooperation and Development (OECD)	•	•	•	•	•	•	•	•
United Nations Economic Commission for Europe (ECE)	•	•				•	•	•
Food and Agriculture Organization (FAO)				•				
Intergovernmental Maritime Consultative Organization (IMCO)		•				•		
International Atomic Energy Agency (IAEA)			•			•		•
International Civil Aviation Organization (ICAO)	•				•			
World Health Organization (WHO)	•	•	•	•	•	•	•	•
World Meteorological Organization (WMO)	•	•						
United Nations Educational, Scientific, and Cultural Organization (UNESCO)	•	•						
United Nations Environmental Program (UNEP)	•	•	•	•	•	•	•	•
Bilateral Cooperation								
Brazil	•	•				•	•	•
Canada	•	•				•	•	•
Federal Republic of Germany	•	•					•	
France		•			•			
France and United Kingdom[d]	•							
Iran	•	•				•		
Israel	•	•						•
Japan	•	•		•		•	•	•
Mexico	•	•	•			•		
Saudi Arabia	•	•				•		
Soviet Union	•	•		•		•		•
United Kingdom	•	•					•	•
Scientific Activities Overseas Program								
Egypt	•	•		•			•	
India	•	•		•			•	•
Pakistan	•	•						
Poland	•	•	•			•	•	•
Yugoslavia	•	•		•			•	•

[a]Includes troposphere and stratosphere.

[b]Includes marine, estuarine, and freshwater environments.

[c]Includes hazardous, solid, and radioactive wastes.

[d]Tripartite agreement.

rino area converted to a different lead isotope ratio in gasoline. This shift gave the lead a unique "fingerprint" which will allow accurate tracking through the ecosystem. The amount of lead in the human blood actually coming from automotive sources will be determined by measuring blood lead levels during the use of this special gasoline and after the area returns to the original gasoline.

Problems concerning the earth's protective ozone layer are also current research issues. Because of this problem's global nature, the United Nations Coordinating Committee on the Ozone Layer reviews ongoing research, identifies research and monitoring needs, recommends (with priorities) needed research projects, and attempts to influence nations and international scientific organizations to conduct such studies. EPA has participated in these discussions and presented the United States position on stratospheric ozone.

EPA also has participated in activities under the Tripartite (France, United Kingdom, and United States) Agreement on Stratospheric Monitoring, which provides a coordinated program of stratospheric monitoring. In general, the Tripartite Agreement has accelerated research within the respective countries, including the application of mathematical models for predicting changes in the stratosphere, research on atmospheric chemistry, and improved methods for measuring stratospheric constituents using satellites, balloons or aircraft, including supersonic transports.

Water quality

A landmark in international cooperation regarding improved water quality is the 1972 United States-Canadian Great Lakes Water Quality Agreement. Now under joint review and revision, this agreement is a unique mechanism for coordinating national efforts on the cleanup and restoration of the Great Lakes. These lakes are crucial. They constitute more than 80 percent of the fresh surface water area of the United States and 97 percent of its fresh surface water storage. The agreement sets joint water quality objectives, formulates remedial programs, and commits the two governments to provide sufficient funding to achieve the objectives. Both sides have worked closely through the International Joint Commission to support a water quality monitoring program and to jointly set forth the research program necessary to guide and support surveillance activities. EPA personnel have been active on the Water Quality Board, the Research Advisory Board, and committees established to carry out the agreement. The Research Advisory Board plays a major role in the development of water quality objectives. In addition to producing the Toxics Inventory, the Board is also evaluating the health and environmental significance of replacements for phosphates in detergents. A pilot study to assess the value of biological maps and a program to identify unrecognized toxic pollutants are underway. A new initiative, beginning in 1978, will identify those concerns that receive additional regulatory attention. EPA provides expert consultation on a variety of issues related to United States-Canada boundary problems.

EPA's research support of the Great Lakes program includes such activities as producing models for management to aid in the control of phytoplankton, pathway studies for hazardous substances, sediment-water interaction modeling, and studies of the impacts from nonpoint sources and thermal discharges on the biota of the Lakes. This research program is one of the few ongoing large scale ecosystem studies of a long-term nature.

Research activities are instrumental in identifying problem areas in the Lakes (e.g., eutrophication in Lake Erie, PCBs in Lake Michigan, Mirex, and other contaminants). These efforts have subsequently led to the recommendation and, in some cases, adoption of new control programs to help restore beneficial uses of the Lakes.

Both countries are also exchanging information on methods for setting water pollution standards and comparing information on toxicology methods including biochemical, microbial, and analytical chemical methods. EPA is conducting joint laboratory efforts on microbiological degradation of toxic substances related to water quality monitoring in water bodies.

Wastewater treatment

To improve knowledge of wastewater treatment and disposal methods, EPA is participating in international research involving source characterization of pollution, advanced wastewater treatment technology, process modification, and analyses of sludges and their environmental behavior. One of the most important of these efforts is the study of advanced wastewater treatment being conducted under the auspices of NATO's Committee on the Challenges of Modern Society (CCMS). The United States, United Kingdom, Canada, Italy, France, and Germany are studying such topics as the standardization of formats for international information exchange, the use of oxygen-enriched air to treat contaminated effluent, land spreading of sludge, nutrient removal, reverse osmosis, electrodialysis, and ion exchange.

Details on these advanced methods of wastewater treatment used abroad are helping EPA to determine which treatment methods may be feasible for use in the United States. For example, Japan has given EPA technological information applicable to United States problems, e.g., the best available technology (BAT) research on tannery wastes. A large scale pilot plant operation in Japan is testing four different pure oxygen systems on the same tannery waste under the same conditions but utilizing different operational techniques. The efficiency and effectiveness of each will be evaluated by the Japanese and a full scale system will be installed. These results will be of immense value to EPA effluent guideline and enforcement offices as well as of direct value to the tanning industry.

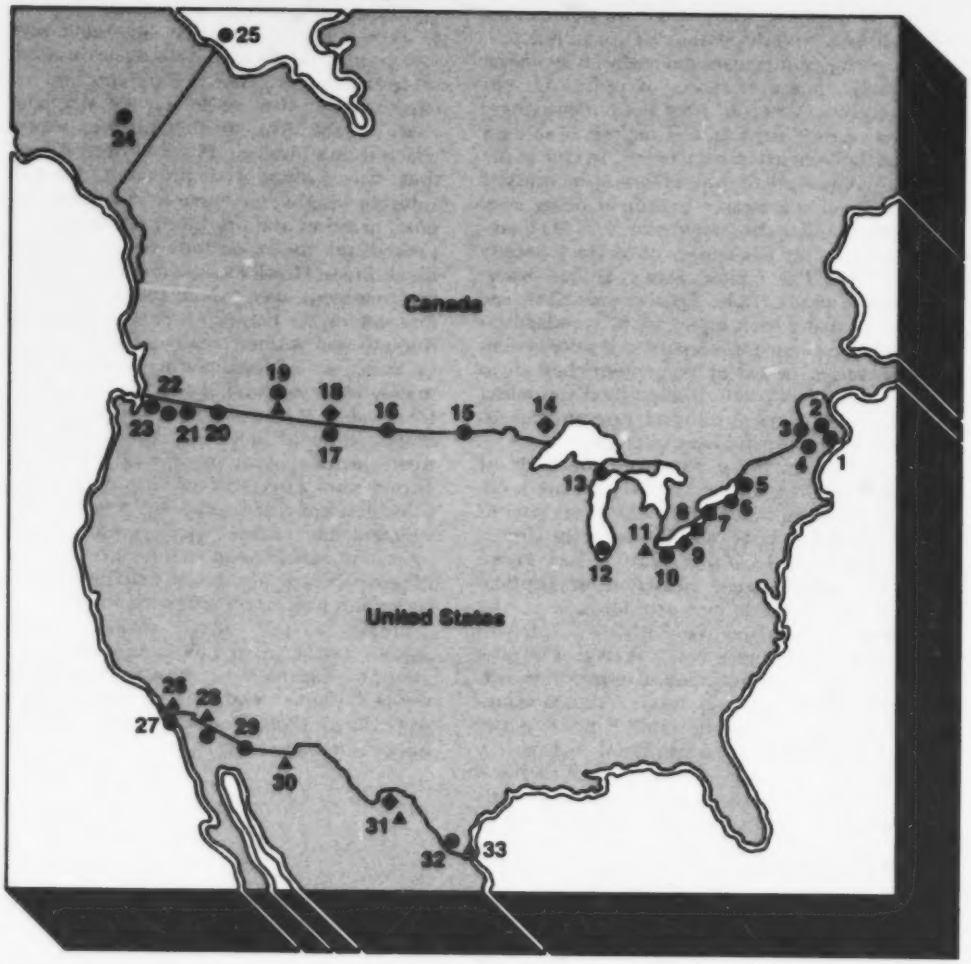
In the Soviet Union there is an accelerated water pollution control effort in both fundamental and applied research. The US-USSR Working Group on Prevention of Water Pollution from Industrial and Municipal Sources is discussing various phases of new Soviet technologies including electrolytic coagulation, high energy magnetic separation, freezing, ozonation, dissolved air flotation, and air stripping. Areas of direct technological benefit can be found in the treatment of industrial and municipal wastewaters and process modifications such as dry formation of paper. Such involvements should, in the near future, provide additional benefits to us not only in terms of cleaner processes and more effective control technologies, but also in terms of a vastly improved understanding of the systems involved.

Hazardous waste

EPA is also working with various countries to assess risks and benefits associated with various methods of hazardous waste disposal. Of key interest is a NATO Committee on the Challenges of Modern Society (CCMS) pilot study on the disposal of hazardous wastes which is now entering Phase II of its operation. Phase I of the study provided EPA with valuable insight into mine and landfill disposal practices and produced recommended procedures for hazardous waste management. Phase II will include analyses of thermal treatment, such as land and sea incineration systems for hazardous wastes, of landfill disposal and surface treatment with a focus on wastes from electroplating and steel hardening processes, and of alternatives to landfill disposal. Areas of potential future cooperation under a United States-Japan bilateral treaty include pyrolysis of solid waste, environmental effects of vinyl and polyvinyl chlorides, improved collection systems management and technology, hazardous waste treatment and disposal technology, recovery of past consumer waste, and management information systems on industrial wastes.

Finally, as part of the revised United States-Canada Great Lakes Agreement, an annex on hazardous substances is being developed. To this end, EPA is establishing a scientific data base for categorizing particular hazardous substances.

Environmental Issues and Projects



Legend:

1. Eastport
2. St. Croix River Basin
3. St. John River
4. Dickey-Lincoln Dam
5. Richelieu-Champlain
6. Reynolds Metals
7. Prescott-Brockville
8. Darlington
9. Nanticoke
10. Lake Erie
11. Detroit-Windsor
12. Great Lakes
13. Lake Michigan
14. Atikokan
15. Rainy River
16. Red River
17. Garrison Diversion
18. Boundary Dam
19. Poplar River Plant
20. Flathead River/Cabin Creek Mining
21. Okanogan River
22. Skagit River
23. Puget Sound
24. Yukon River Basin
25. Beaufort Sea
26. San Diego-Tijuana
27. San Diego-Tijuana
28. Calexico-Mexicali
29. Nogales-Nogales
30. El Paso-Cuidad Juarez
31. Eagle Pass-Piedras Negras
32. Laredo-Nuevo Laredo
33. Brownsville-Matamores

- ● Water
- ■ Nuclear Power Plants
- ◆ Coal-Fired Plants
- ▲ Air Pollution

Energy

With the increasing focus on coal as a future energy source, much can be gained from the experience of other countries in exploiting this fuel. An excellent example of this potential is a study currently underway with Yugoslavia. The project is providing a full evaluation of the Kosovo Coal Gasification Plant, its effluent and process streams, and pollution control systems. With the current United States effort to commercialize coal gasification, it is essential for EPA to assess the environmental consequences which will result from coal conversion technology. The pollutant data and evaluation obtained by the study in Yugoslavia will be used by EPA to determine the potential impact of gasification plants proposed for the United States and the criteria required for control technology development.

Also related to coal use, in 1977 the United States and the Federal Republic of Germany initiated a cooperative program on the control of emissions from coal-fired facilities. EPA and the German Ministry of Research and Technology have agreed to exchange information and, in certain cases, to work together to assure efficient development of technologies capable of allowing coal burning in an environmentally acceptable manner. Included in this cooperative effort are the control technologies of sulfur oxides (including utilization of by-products), nitrogen oxides, and particulates.

The Agency is also working on four projects under a United States-Soviet Union Environmental Agreement which concern gaseous emission, particulate abatement technology, process improvement and modification, ferrous metallurgy, and a new United States initiative—protection of the environment from coal preparation plant operations. Both countries are examining questions related to the abatement of sulfur dioxide emissions through various control techniques using lime/limestone, magnesia, and ammonia scrubbing; dust collection technology; characterization of aerosols; demetallization pretreatment for the hydrodesulfurization of petroleum residuals; preliminary coal cleaning; and complex methods for fuel utilization in power generating systems for the elimination of harmful emissions.

Monitoring

In addition to its activities on the Stratospheric Ozone Monitoring Program, EPA has the lead responsibility to fulfill the international monitoring program on the Great Lakes, under the 1972 United States-Canadian Water Quality Agreement. International coordination of monitoring activities is achieved through the surveillance subcommittee of the Water Quality Board. This subcommittee assures that appropriate measurements are taken for use in the management models for nutrients. The resulting data are shared by the two countries. Currently, intensive efforts on each Lake occur only every five years. The Research Advisory Board, however, feels that more effort is needed on biological monitoring to improve our understanding of trends in the Great Lakes.

EPA is also active in the United Nations Environmental Program's Global Environmental Monitoring System. Primarily concerned with air, this system will link existing national monitoring activities. United States cooperation in the global water quality monitoring network is expected to increase as a result of EPA's role as a World Health Organization Collaborating Center for Environmental Pollution Control. The data from joint surveillance and monitoring in the Great Lakes will be incorporated into the Global Environmental Monitoring System.

A comprehensive environmental monitoring program is a prerequisite for complete United States participation in the establishment of a global monitoring system and our utilization of data from it. This international coordination, as well as the development of our own national monitoring capability, will increase our base of knowledge on pollutant build-up in the environment before that build-up reaches crisis proportions.

Conclusion

These are but a few of EPA's research-related international activities. They reflect areas of concern, as well as some of the countries and organizations with which EPA research works. In the future, the Agency will continue to identify and initiate needed international research projects and will continue its activities of coordination. There are challenges and opportunities for positive action on international environmental problems and EPA will continue to play a major role.

Community health and environmental surveillance system

3

Introduction

On November 24, 1976, the House Subcommittee on the Environment and Atmosphere of the Committee on Science and Technology released a report titled, "The Environmental Protection Agency's Research Program with Primary Emphasis on the Community Health and Environmental Surveillance System (CHESS): An Investigative Report" (Ref. 1). The Environmental Research, Development, and Demonstration Authorization Act of 1978 (P.L. 95-155) specifies that EPA shall report the implementation status of the Investigative Report's recommendations in each annual revision of its five-year plan. This is the first EPA implementation status report.

Background

CHESS emerged as a major program in 1970. A discussion of goals and objectives is in "Environmental Science and Technology" (Ref. 2). CHESS was designed, as the name indicates, to monitor the health status of the United States population with respect to varying environmental conditions. For the most part, the environmental considerations were limited to meteorologic conditions and pollution levels. The program included studies of health groups and potentially susceptible groups such as asthmatics. CHESS data, gathered over five years, have been analyzed for relationships between health effects and exposure to such pollutants as sulfur oxides, nitrogen oxides, particulate matter, and oxidants.

In May 1974, EPA published the "Health Consequences of Sulfur Oxides: A Report from CHESS, 1970-1971" (often referred to as the CHESS Monograph) that included several of the early CHESS aerometric and health studies (Ref. 3).

On February 29, 1976 the *Los Angeles Times* published the first of several articles implying that studies in the CHESS Monograph on the health effects of ambient sulfur oxides were distorted (Ref. 4). Basically, the *Times* articles made three allegations: (1) the analysis of the CHESS data shows a stronger than actual correlation of adverse health effects with increased levels of ambient sulfate; (2) Dr. John F. Finklea was responsible for the distortion, with the passive assistance of his subordinates; and (3) the EPA regulatory program for sulfur oxides rests solely on the CHESS program.

On April 7, 1976, an EPA investigative task force appointed to review the entire matter reported its findings (Ref. 5). This group interviewed most of the EPA employees who participated in the CHESS data analysis. From these interviews, it became apparent that comments of EPA personnel made to the *Times* reporter referred to the 1972 draft version of the report, and not to the final publication of 1974. The group's unanimous opinion concerning both the draft and final versions was "that there is no evidence of dishonesty or deliberate distortion of data by Dr. John F. Finklea or members of his staff who worked on the Monograph. On the contrary, there is evidence of an honest and aggressive effort to publish the sulfur oxide findings from the CHESS studies so that they would be available in a timely fashion for use by the Agency and the public at large."

On April 9, 1976, the allegations concerning the CHESS report and the *Times* articles were the subject of a Congressional hearing convened by two House Committees: Science and Technology and Interstate and Foreign Committee (Ref. 6, pp. 23-24). Three of the Committees' conclusions, which directly relate to the *Los Angeles Times* allegation, are:

—"There was agreement that the CHESS studies confirm an association between sulfur oxides emissions and adverse health effects."
—"There was no evidence that Dr. Finklea tampered with, distorted, or withheld data."
—"The National Ambient Air Quality Standards (NAAQS) for sulfur dioxide were set before CHESS, and were based on other data."

An examination of the *Times* articles and the Congressional hearing is published in *Science* and the *Environmental Health Letter* (Ref. 7, 8).

The House Committee on Science and Technology started an investigation concerning technical issues relating to CHESS in April of 1976. The Committee released the Investigative Report on November 24, 1976 (Ref. 1).

Investigative report recommendations

The recommendations in the Investigative Report concern two major topics: the scientific assessment of the CHESS program, and the present and future management of EPA research. EPA agrees with many of the Investigative Report's statements and recommendations regarding the quantitative limitations of the CHESS results. Also, EPA concurs with the majority of the recommendations for the

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improvement of research. The implementation status for each recommendation is discussed in the following paragraphs.

Recommendation 3 CHESS Monograph

Recommendations 3(a), (b), and (c) in the Investigative Report concern the CHESS Monograph. Recommendation 3(b) directs that the Monograph should not be used without explicit qualifications. Recommendations 3(a) and 3(c) state that EPA should publish an announcement regarding the limitations of the Monograph and publish an addendum to the Monograph (including at least Chapters IV, V, VI, and Appendix A of the Investigative Report). Prior to presenting our response to these recommendations, the EPA air health effects research program, the CHESS Monograph, and EPA's regulatory responsibilities will be placed in perspective.

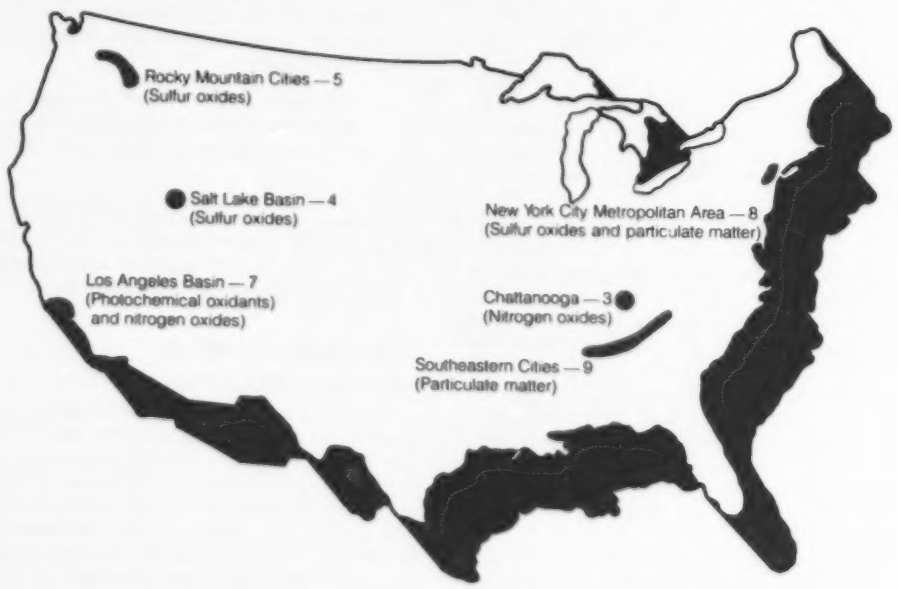
The air health effects research program uses a combination of research approaches: human epidemiological studies, human clinical studies, and toxicological studies on animal models (Ref. 9). Integrating the capabilities and advantages of these approaches provides the best overall scientific strategy for informed regulatory decisions. Concerning the CHESS program, epidemiologic investigations offer the advantages of studying the biological responses of people, including vulnerable groups, under ambient conditions.

The major problems are related to quantifying the exposure, dealing with many typically unknown covariates, and interpreting association vs. causation. Several publications, including the Investigative Report, contain detailed explanations of the strengths and weaknesses of epidemiology (Ref. 1, pp. 57-58; Ref. 10, pp. 16-17; Ref. 11, pp. 16-17).

EPA acknowledges the limitations of individual epidemiologic studies. For example, the Summary and Conclusions of the CHESS Monograph states:

"The findings summarized in this paper must be substantiated by replicated observations in different years and under different circumstances. Well controlled human and animal studies are required to isolate several of the important intervening variables that are inherent to studies of free living populations, and to elucidate the precise nature of the pollutant-disease relationship. Hence, the conclusions put forth at this time cannot be definitive, but are offered in the sense of developing more refined quantitative and scientific hypotheses concerning pollutant-health effect associa-

CHESS Study Areas



Note: Numbers indicate number of neighborhoods studied per area.

tions in a real life environment." (Ref. 3, p. 7-4).

Most epidemiologic studies are open to criticism and this was the reason spatial and temporal replication was fundamental to the CHESS designs. Further, in practically all areas of epidemiology, conclusions rest on the weight of evidence from many studies, not on individual studies. Thus, there is ample justification to cite CHESS studies as they bear on existing EPA standards. An important feature of several of the CHESS studies reported in the Monograph is their general consistency with the majority of epidemiologic, clinical, and toxicologic studies previously published in the sulfur oxides and particulate matter literature. The CHESS studies tend to support the reasonableness of existing ambient air quality standards for sulfur oxides and particulate matter. However, EPA agrees that there is far too much uncertainty and lack of qualification in findings contained in the Monograph to support any new or modified air quality standards.

Finally, the Monograph assessments of current pollution exposure were among the most complete that had ever been performed within the then existing state-of-the-art. These epidemiologic findings, although having a limited ability to affect EPA regulatory policy, have materially advanced our knowledge concerning the general distribution and behavior of the exposure-response variables employed.

Misunderstandings still exist, however, over the CHESS Monograph and EPA's regulatory posture on sulfur oxides. Therefore, this report to the Congress shall be widely circulated and sent to all holders of the CHESS Monograph with an appropriate cover letter. With this action, EPA believes that the intent of Recommendation 3 will be adequately implemented.

Recommendation 4 research responsibilities

Recommendation 4 addresses research responsibilities and resources. Recommendation 4(a) directs that legislation should be reexamined regarding unrealistic procedures and schedules. Legislative mandates are the most important considerations in the annual program planning process. EPA maintains an in-house research capability and expertise to respond to short deadlines. However, when procedures or schedules are unrealistic, the Congress and the Office of Management and Budget (OMB) are informed by either the normal budget submission process, during oversight hearings, or by other appropriate mechanisms. Recommendation 4(b) specifies that research be designed to gain information and not support positions. The Office of Research and Development is organizationally separated from offices having regulatory responsibilities. Therefore, scientists conduct research to gain accurate information and are not under pressure to support existing or preconceived positions held by the regulatory offices. The Science Advisory Board, an independent advisory body, has established a Subcommittee on Epidemiological Studies to independently review EPA's epidemiology (Ref. 12). Recommendations 4(c) and (d) concern the Office of Management and Budget allowing all necessary funding for expeditious research and advising the Congress of budgetary restrictions affecting completion of major projects. Through the normal budgetary process, the Office and the Congress are advised for EPA resource requirements and which programs are affected by budgetary restrictions.

Recommendation 5 questionnaires

Recommendation 5 advises that the OMB should be asked to develop procedures for prompt review of questionnaires. OMB and EPA's research managers and scientists have discussed this matter. These discussions have expedited questionnaire clearances. However, the total number of questionnaires allocated to EPA is small and therefore limits the number of epidemiologic studies that can be performed (Ref. 13). The control of questionnaires by the Federal Government was intended to reduce involuntary solicitations from the private sector. Only selected volunteers participate in EPA's epidemiologic studies. Therefore, we believe that EPA's voluntary questionnaires should be free of allocation limitations.

Recommendation 6 CHESS data

Recommendation 6 concerns the processing and publication of the remaining CHESS data. Recommendation 6(a) directs that unanalyzed data be examined and that analyses be carried out on those data that appear to have a higher degree of validity than the CHESS Monograph data base. In general, the quality of the CHESS data improved as experience was gained. Therefore, a plan has been developed for validation of 61 of the 65 data sets for which reports have not yet been published (Ref. 14). Four episode studies will not be validated because their usefulness is

questionable. Recommendations 6(b) and (c) concern publishing research in traditional, refereed, archival, journals and not publishing solely in monograph form. EPA endorses this policy. Independent university scientists are being used to analyze, interpret, and report on appropriate CHESS data. Manuscripts of research investigations are being submitted for publication in the scientific literature as relevant studies are completed. As of December 1, 1977, there have been 28 CHESS publications in scientific journals (Ref. 15). Monographs are, and have mainly been, used as a vehicle to present all pertinent data that would be inappropriate for publication in scientific journals. Recommendation 6(d) states that projects for policy considerations should not be initiated unless they can be completed in a realistic time frame and unless the research staff can be involved in the process. Several mechanisms have been incorporated to develop achievable program plans. These include a joint program planning process where the staffs of the research laboratories and headquarters, and the program offices participate. In addition, laboratory program reviews are conducted and problems associated with the implementation of investigations are discussed and resolved.

Recommendations 7, 8, and 10(b)—CHAMP

Recommendations 7, 8, and 10(b) are directed toward CHAMP, EPA's Community Health Air Monitoring Program. Recommendation 7(a) states that the aerometric and quality control programs should be further strengthened and improved. An expanded quality control program is being implemented in EPA (Ref. 16). Specifically for CHAMP, comparisons for instruments, techniques, and standards are being conducted among the EPA laboratories measuring air quality. In addition, a contractor is providing additional quality control audits of the CHAMP field and laboratory systems (Ref. 17). This includes the use of National Bureau of Standards flow and measurement standards as well as gas mixture standards. Recommendation 7(b) directs a shortening of time between data acquisition and quality assurance analysis of data. The new CHAMP contractor has been given technical direction to minimize the time between data collection and validation (Ref. 18). To accomplish this, software is being developed and maintenance practices have been revised.

Recommendations 7(c) and (d) specify that development stage instruments should not be employed before qualification testing has been done and that laboratory models of instruments should not be used in the field until they have been field checked and operating personnel have been trained. The present CHAMP policy calls for complete checkout, acceptance testing, and personnel training before field placement of any developmental stage instruments. Recommendation 7(e) directs that the opening of the CHAMP operations contract to competition should be reexamined to see whether the merits of open bidding outweigh the problems of instability. This reevaluation took place and it was determined that the merits of open bidding with the possibility of improved performance outweighed any problems of instability. In due course, the contract was awarded to a new contractor after competitive bidding. The transition period between the old and new contractors disclosed several major deficient areas. This finding confirmed the wisdom of the decision to reopen the CHAMP operations contract. Recommendation 7(f) concerns health effects personnel closely coordinating with air quality and monitoring personnel to understand chemical species to be monitored. The CHAMP staff is cooperating closely with the epidemiologists and other health scientists in the design and protocol development for epidemiologic studies. This cooperation includes reaching mutual agreement on chemical species to be monitored.

Recommendation 8 concerns additional meteorological support for health research-air pollution effects studies. This recommendation also directs that meteorological instrumentation be uniform and complete for all stations. There is one full-time meteorologist assigned to the epidemiologic program. He works with both the epidemiologists and CHAMP personnel to assure that the appropriate and uniform meteorological measurements are made. Because of the reduction in the number of epidemiologic studies since the termination of CHESS field studies, the meteorological support to this activity is now at the proper level. Additional meteorological support will be seriously considered if the number of epidemiologic studies is significantly increased.

Recommendation 10(b) directs that instruments and protocols used in CHAMP be verified to ensure reliable data. EPA is testing all instruments in present use for precision and accuracy. The present system of continuous air monitors appears to have a precision and accuracy such that errors are less than plus or minus 15 percent. Third generation instruments are being evaluated when obtained to improve the present system.

Recommendation 9 pollutant characterization

Recommendation 9 directs that the EPA Health Effects program as well as interagency utilization of all available Federal and extramural resources in the health effects area should be examined with the objective of significantly accelerating research in pollutant characterization. Liaison is maintained with other Federal agencies and the non-Federal sector regarding air pollution characterization. In accord with the 1977 Clean Air Act Amendments, EPA has organized an interagency task force to determine the effects of environmental pollutants on cancer, heart, lung, and other chronic diseases (Ref. 19). In addition, on a case by case basis we are examining the proper balance between pollutant characterization and health effects research. Adjustments are being made as deemed appropriate. We fully appreciate, for example, the necessity of having adequate pollutant characterization data prior to the beginning of laboratory toxicologic experiments. The same principle clearly applies to epidemiologic research.

Recommendations 10(a), 10(c), 12(a) and 12(d)—peer review

Recommendations 10(a), 10(c), 12(a) and 12(d) concern peer review. Recommendation 12(d) concerns expanding the Science Advisory Board charter. The charter has been modified in accord with the Environmental Research, Development, and Demonstration Act of 1978 (Ref. 20). Under the previous and new charter, the Board is authorized to conduct peer reviews. The Board, an independent advisory body, decides how it will respond to requests for assistance. The Office of Research and Development encourages the Board to conduct such reviews. However, it is impossible for the Board to review all research programs because of the limited time Board members can devote to EPA activities. The Office of Research and Development has started discussions with the Board to establish a more effective internal peer review process.

Recommendation 10(a) states that a truly interdisciplinary task force led by an eminent scientist should draw up a program plan for EPA to develop a solid base for knowledge and procedures in aerometric instrumentation and measurements, meteorology, field data gathering, quality control, epidemiology project design and testing, and panel planning. This recommendation will be discussed with the Board. The activities of several groups are pertinent to the recommendation. The Board's Subcommittee on Epidemiological Studies provides advice and assistance in the review and evaluation of proposed or existing programs of epidemiologic studies relating to the health effects of environmental pollutants (Ref. 13). Interactions between our scientists and this subcommittee are continuing. The Environmental Measurements Advisory Committee has visited several EPA laboratories and evaluated current analytical methods and instrumentation research (Ref. 21).

Recommendation 10(c) directs that EPA should have epidemiological questionnaires and panel selection criteria approved by peer groups before the next round of investigations. Specific questions that must be resolved are identified. Regarding the latter, all questions are presently being addressed either by the in-house staff or through contracts. As mentioned previously, the matter of peer reviews is being discussed with the Board.

Recommendation 12(a) directs EPA to establish authoritative peer review panels to assist in improving research coordination. This is being discussed with the Board.

Recommendation 10(d)—ideas

Recommendation 10(d) instructs that EPA should review several ideas raised in the investigation team interviews. These have been reviewed and some have been incorporated into the epidemiology program.

Recommendation 11 reorganizations

Recommendation 11 states that no significant reorganization should occur at Research Triangle Park's Environmental Research Center until the end of Fiscal Year 1977. No significant reorganizations have occurred during that specified time period.

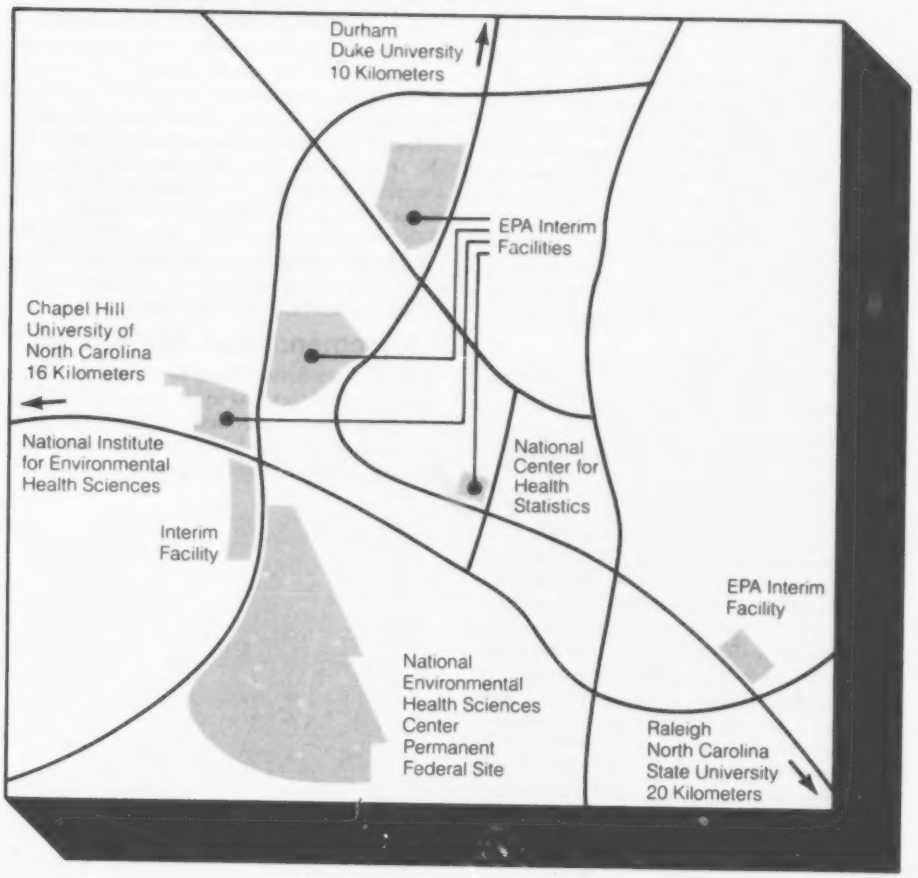
Recommendation 12(b) management

Recommendation 12(b) instructs that EPA should have a stronger focus on management at the Environmental Research Center, Research Triangle Park, North Carolina. In its laboratory reorganization, the Office of Research and Development established a line structure with accountable managers directing the research programs at each laboratory. In turn, each laboratory has programs assigned on the basis of scientific areas that are carried out by its complement of scientists and engineers. In addition to the line management of each laboratory, the Research Triangle Park includes an office of the senior research and development official. Essentially, this official (who is also a Laboratory director) is responsible to the Assistant Administrator for Research and Development to assure effective operation and administration in the laboratories.

Recommendation 12(c) systems analysis

Recommendation 12(c) instructs that EPA should create a systems analysis-operations research program review group. Using sys-

Federal Health Facilities in Research Triangle Park, North Carolina



tems analysis and operations research as tools, significant program reviews are carried out by the Office of Planning and Management in its Program Evaluation Division. As needed, the Division:

—Assembles and evaluates scientific, technological, cost, benefits, and institutional data to critique existing program activities, and recommends alternatives.
—Develops a long-range policy framework for EPA goals and objectives in consultation with other Agency offices; identifies strategies for accomplishing these goals; and assures that program activities are evaluated in relation to such strategies.
—Conducts and coordinates analyses and evaluations of Agency-wide programs, including those crossing EPA organizational lines.

Recommendation 13 technical exchange

Recommendation 13 relates to the EPA research program and maximal technical exchange. Recommendation 13(a) directs that EPA should seek cooperative research programs with universities and other laboratories and agencies. The research program in EPA has a large extramural component involving research grants with universities and interagency agreements with other Federal organizations. For example, the overall coordination and detailed planning of the Interagency Energy/Environment Program is the responsibility of the EPA (Ref. 22). Research and development activities under this program are performed by several agencies in addition to EPA. Also, most of the EPA research laboratories are located on university campuses, or in research parks developed by universities, and have close working relationships with nearby institutions. Recommendation 13(b) directs that EPA should promote the exchange of scientists both within and outside the Agency. Over the last few years, the Office of Research and Development has used the Intergovernmental Personnel Act mobility program. This program authorizes the temporary exchange of career employees between the Federal Government and state and local governments, institutions of higher education, and Indian tribal governments. Currently, 66 individuals are participating in the Office's mobility program.

Recommendations 13(c) and (d) concern EPA of funding individual Ph.D. thesis research and the Science Advisory Board development of outreach programs. The Office of Research and Development will discuss these recommendations with the Science Advisory Board and specifically seek their assistance in developing effective outreach programs. Board members have provided general comments but have not yet undertaken any formal actions related to outreach programs.

Recommendations 14 and 17 research role

Recommendations 14 and 17 state that the EPA Administrator should clarify the role of the Office of Research and Development and determine if research should be conducted in its present organizational configuration. EPA is preparing a report to the Congress on planning and management of the Agency's research and development activities. This report will address the most appropriate means of assuring, on a continuing basis, that research in the Agency reflects the needs and priorities of the regulatory program.

Recommendation 15—facilities

Recommendation 15 directs EPA to resolve the separation of facilities at Research Triangle Park. This is the largest EPA field facility and is located in North Carolina within the geographical triangle bounded by the North Carolina cities of Raleigh, Durham, and Chapel Hill. In this area, three major EPA components with a total of 1,857 employees and contractors occupy leased space in nine buildings. In 1967, a 509-acre tract at the Park was donated to the Federal Government for the construction of the National Environmental Health Science Center. An overall master site plan was completed in 1971 and EPA was assigned a 44-acre site for construction of a permanent facility (Ref. 23). Recently EPA developed a long-range space plan for its activities in the area (Ref. 24). This plan is presently under consideration.

Recommendation 16 career development

Recommendation 16 states that EPA management should develop, implement, and defend a professional career development program for each professional. It is the policy of EPA to plan and provide for the training, development, and necessary career planning for employees (Ref. 25). In July 1977, the Agency strengthened existing mechanisms to insure adequate career development (Ref. 26). As part of their annual performance evaluation, supervisors are required to develop a yearly training plan for each employee.

Resolution of Investigative Report Recommendations

Number	Summary of Recommendations	Action
3(a)	EPA should publish an announcement regarding the limitations of the CHESS Monograph.	Shall be implemented
3(b)	EPA should not use the CHESS Monograph without explicit qualification.	Shall be implemented
3(c)	EPA should publish an addendum to the CHESS Monograph including most of the Investigative Report.	Shall be implemented
4(a)	Legislation should be reexamined regarding unrealistic procedures and schedules.	Implemented
4(b)	EPA should design research to gain information and not support positions.	Implemented
4(c)	OMB should allow all necessary resources if public policy requires expeditious research.	Implemented
4(d)	EPA should advise Congress if budgetary restrictions will impact completion of major projects.	Implemented
5	OMB should be asked to develop procedures for prompt review of questionnaire.	Implemented
6(a)	CHESS date analyses should be carried out only on data with high validity potential.	Implemented
6(b)	EPA should publish research in refereed journals in a timely fashion.	Implemented
6(c)	EPA should not publish large projects solely in monograph form.	Implemented
6(d)	EPA should not initiate projects for policy consideration unless they can be completed in a realistic time frame.	Implemented
7(a)	EPA should strengthen the CHAMP aerometric and quality control programs.	Implemented
7(b)	EPA should shorten the time between data acquisition and quality assurance analysis of data.	Implemented
7(c)	EPA should stop employing development stage instruments before qualification testing.	Implemented
7(d)	EPA should not use laboratory models of instruments in the field until they have been field checked and operating personnel trained.	Implemented
7(e)	EPA should reevaluate the opening of the CHAMP operations contract to competition.	Implemented
7(f)	EPA research and monitoring personnel should closely coordinate regarding chemical species.	Implemented
8	EPA should have additional meteorological support for air pollution health effects research studies.	Implemented

Number	Summary of Recommendations	Action
9	EPA should examine accelerating research in pollutant characterization.	Implemented
10(a)	An interdisciplinary task force should draw up an integrated air epidemiology-exposure assessment program plan for EPA.	Under consideration
10(b)	CHAMP should verify instruments and protocols so that reliable data can be achieved.	Implemented
10(c)	EPA should have epidemiological questionnaires and panel selection criteria approved by peer groups.	Under consideration
10(d)	EPA should review research concepts obtained from team interviews.	Implemented
11	The Environmental Research Center at Research Triangle Park (RTP) should not be reorganized until the end of FY 77.	Implemented
12(a)	EPA should establish authoritative peer review panels to assist in improving research coordination.	Under consideration
12(b)	EPA should have a stronger focus on management at the Environmental Research Center, RTP.	Implemented
12(c)	EPA should create a systems analysis-operations research program review group.	Implemented
12(d)	The Science Advisory Board's charter should be expanded.	Implemented
13(a)	EPA should seek cooperative research programs with universities and other laboratories and agencies.	Implemented
13(b)	EPA should promote the exchange of scientists within and outside the Agency.	Implemented
13(c)	EPA should fund individual Ph.D. thesis research.	Under consideration
13(d)	The Science Advisory Board should develop outreach programs.	Under consideration
14	The Administrator should clarify the role of the Office of Research and Development and its laboratories.	Shall be implemented
15	EPA should resolve the separation of facilities at RTP.	Under consideration
16	EPA should develop a professional career development program for each professional employee.	Implemented
17	The Administration should determine if EPA should conduct research under its present organizational configuration.	Shall be implemented

Office of research and development

4

The Office of Research and Development functions as the principal scientific component of EPA under the direction of one of the six assistant administrators of the Agency. Its fundamental role is to assess and produce scientific information and technical tools as a basis for sound national policy in the development of effective pollution control strategies and reasonable environmental standards. The Office of Research and Development addresses the following questions:

—How can pollution be identified, measured, and monitored?
—What are the relationships between pollutant discharges and environmental degradation?
—What levels of pollutant discharge from specific sources can be permitted while still attaining defined environmental standards?
—What are the effects of pollutants on people, other life forms, and the inanimate environment?
—What techniques are available for controlling pollution?
—How can environmental quality best be maintained and improved?

More than 1,700 employees of the Office of Research and Development carry out this program with a budget of about $300 million per year. The staff is composed of professionals in 60 disciplines located nationwide in 15 major laboratories and one headquarters office. All personnel, scientists, and engineers contribute to a research program that consists of in-house activities as well as programs shared with the academic community, the private sector, and numerous Federal, State, and local agencies.

The budget of the Office of Research and Development increased from about $102 to $144 million over the Fiscal 1971 through 1974 period. In 1975, the Interagency Energy/Environment R&D Program resulted in a substantial increase in the Office's activities and budget.

The number of permanent personnel in the Office of Research and Development reached a peak of 1,914 in Fiscal 1973. The total number of authorized personnel for Fiscal 1978 is 1,729.

EPA's research program is multidisciplinary, covering several legislative authorizations. For purposes of budgetary authorization and appropriation, programs are classified as follows:

—Air
—Water Quality
—Solid Waste
—Pesticides
—Radiation
—Water Supply
—Toxic Substances
—Energy Research

Health effects research assesses health hazards resulting from environmental pollution covering several categories including air, water, pesticides, radiation, water supply, and toxics. Research problems are classified according to exposure levels, perceived effects, and the need to take regulatory actions to protect people.

Ecological processes and effects research focuses on the effects of atmospheric, aquatic, and terrestrial pollutants on the structure and function of ecosystems and their biotic and abiotic subcomponents.

Transport and fate of pollutants research examines the biological, chemical, and physical phenomena affecting pollutants as they migrate from sources to receptor and otherwise transform and persist in the ambient environment. Empirical and analytical techniques are developed that relate atmospheric, aquatic, and terrestrial pollution to sources and receptors.

Minerals processing and manufacturing research addresses point sources of pollution from industrial sectors, especially those from mining, manufacturing, services, and trade industries that extract, produce, and process nonenergy materials into consumer products. Methods to control and prevent environmental degradation resulting from accidental spills of selected materials are also researched.

Renewable resources research encompasses development of total management systems to control air, water, and land pollution resulting from the production and harvesting of food and fiber and their related residual wastes. Predictive methods are developed and probable trends in production of renewable resources and resulting environmental impacts are assessed. An example is the dem-

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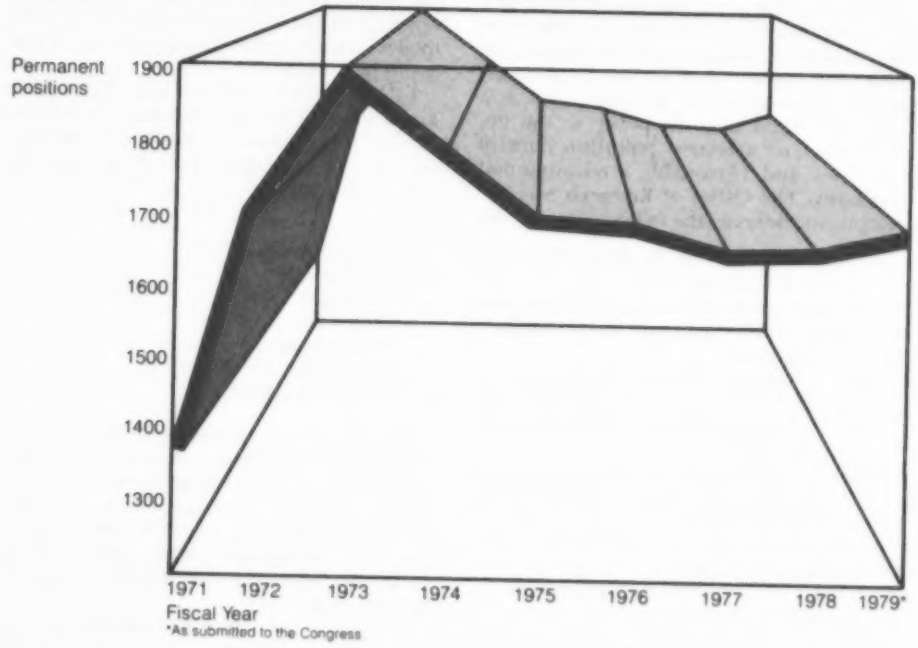
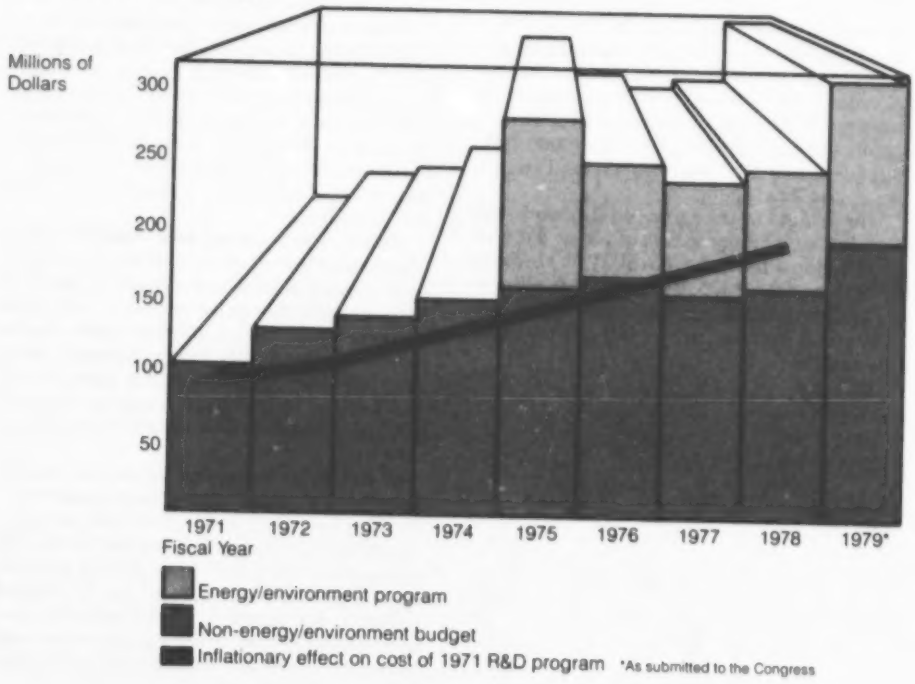
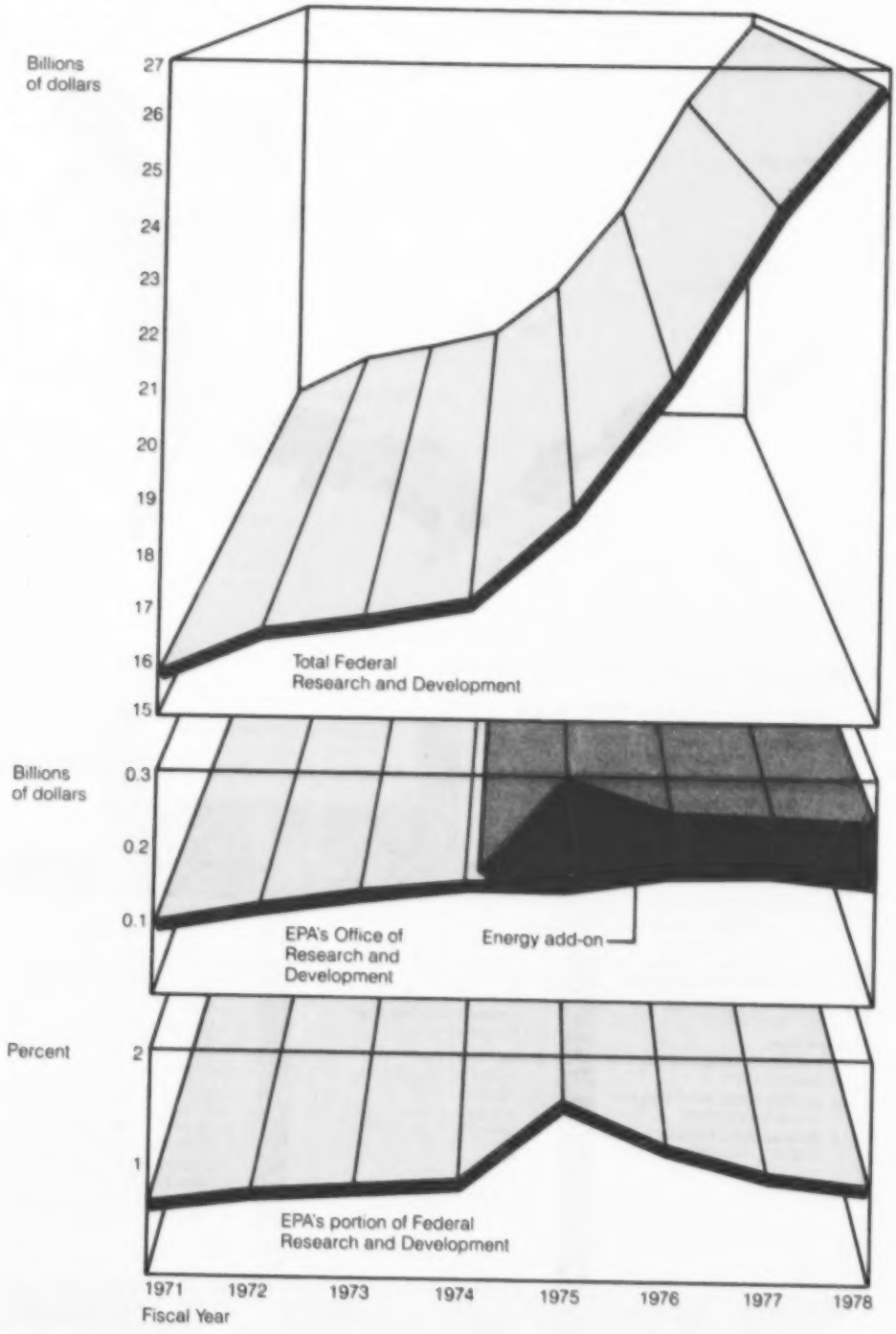
Historical Trend of ORD's Permanent Positions



Trend of ORD Budget

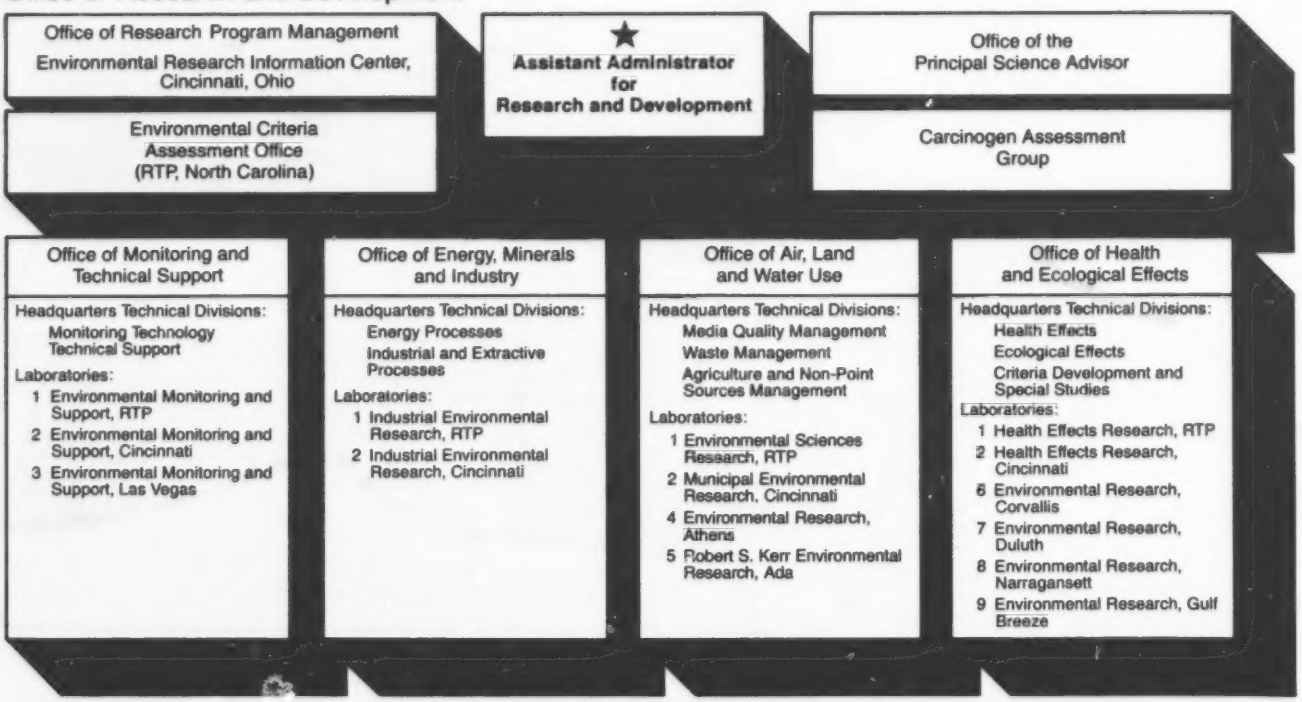


ORD Portion of Federal Research and Development



ORD Laboratories

Office of Research and Development


Office of Research Program Management
Environmental Research Information Center, Cincinnati, Ohio
Environmental Criteria Assessment Office (RTP, North Carolina)
Assistant Administrator for Research and Development
Office of the Principal Science Advisor
Carcinogen Assessment Group
Office of Monitoring and Technical Support
Headquarters Technical Divisions:
Monitoring Technology
Technical Support
Laboratories:
1 Environmental Monitoring and Support, RTP
2 Environmental Monitoring and Support, Cincinnati
3 Environmental Monitoring and Support, Las Vegas
Office of Energy, Minerals and Industry
Headquarters Technical Divisions:
Energy Processes
Industrial and Extractive Processes
Laboratories:
1 Industrial Environmental Research, RTP
2 Industrial Environmental Research, Cincinnati
Office of Air, Land and Water Use
Headquarters Technical Divisions:
Media Quality Management
Waste Management
Agriculture and Non-Point Sources Management
Laboratories:
1 Environmental Sciences Research, RTP
2 Municipal Environmental Research, Cincinnati
4 Environmental Research, Athens
5 Robert S. Kerr Environmental Research, Ada
Office of Health and Ecological Effects
Headquarters Technical Divisions:
Health Effects
Ecological Effects
Criteria Development and Special Studies
Laboratories:
1 Health Effects Research, RTP
2 Health Effects Research, Cincinnati
6 Environmental Research, Corvallis
7 Environmental Research, Duluth
8 Environmental Research, Narragansett
9 Environmental Research, Gulf Breeze

onstration of pest management strategies to minimize the usage and runoff of agricultural pesticides.

Waste management research focuses on the prevention, control, treatment, and management of pollution resulting from wastewater discharges from community, residential, or other nonindustrial activities, including urban runoff. Problems associated with the collection, transport, and management of solid wastes are also researched. This subprogram provides technical information to support the Agency's operating program in construction grants, comprehensive water quality planning, and solid and hazardous waste management.

Waste supply research, development, and demonstration activities provide the technology and management criteria necessary to maintain dependably safe surface and groundwater supplies of drinking water. Health effects resulting from contaminants in drinking water are also studied.

Environmental management research develops improved procedures for planning, implementing, enforcing, and assessing cost-effective environmental protection strategies for particular problem areas such as air and water. Institutional, economic, and decision-making problems faced by governmental multimedia environmental programs at local, State, and regional levels are analyzed. New management methods for implementing environmental protection plans are evaluated.

Characterization and measurement methods development provides methods and instrumentation for all pollutants (pesticides, toxic substances, industrial chemicals, petrochemicals, combustion products, etc.) in air, land, and water (surface and groundwaters). Research deals with the basic physical and chemical parameters of pollutants and the development of instruments to detect and quantify pollutants.

Measurement techniques and equipment standardization research provides reference methods, sampling procedures, and monitoring systems so that standardized techniques are available for monitoring the environment.

Quality assurance provides methods and criteria for establishing validated measurement systems and conducts quality control activities to assure the intercomparability of all monitoring data. This program provides standard reference materials and samples, develops quality control guidelines and manuals, conducts on-site evaluations of analytical laboratories, and makes interlaboratory performance checks to assure that legally defensible data are produced by EPA laboratories.

Technical support is a scientific and technical consultative service provided to other organizations within EPA to solve immediate problems through the use of specialized expertise and facilities. The activities typically require analytical measurement or monitoring.

Technical information efforts manage and coordinate the effective dissemination of the findings and products of the research program to users within EPA and throughout the public and private sectors.

Energy extraction and processing technology covers the characterization of pollutant sources, assessment of environmental problems, and development of control techniques to mitigate the environmental impact of the extraction and processing of solid, liquid, and gaseous fuels, as well as advanced energy sources such as uranium and geothermal.

Energy conservation, utilization, and technology assessment aim to ensure adequate energy production from fossil fuels with minimum damage to environmental quality. Integrated technology assessments identify environmentally, economically, and socially acceptable alternatives for meeting national energy demands.

Energy health and ecological effects research determines the environmental effects of energy extraction, transmission, conversion and use so that criteria can be developed in a timely manner to protect human health and ecosystems. Identification of pollutants released by energy related industrial operations, and determination of their impact on the environment, aid in defining the pollution control requirements for energy producing operations.

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